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NATURAL VARIABILITY AND CHEMICAL CONTROL
OF THE WILD OAT (AVENA FATUA L.)

Lorne F. Ebell

University of Alberta

October, 1957

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NATURAL VARIABILITY AND CHEMICAL CONTROL
OF THE WILD OAT (AVENA FATUA L.)

A DISSERTATION
SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES
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ABSTRACT

Wild oats from grain samples collected in 1951 from nine locations in Alberta were sown under uniform conditions at Edmonton in 1952 and 1953. Marked differences in emergence and development occurred and it was evident that the wild oat seed of most sources represented a very mixed population. The progenies of 22 plants each, of Didsbury and Moon Lake origin, were grown at Edmonton in 1953. Marked variation occurred between the individual plant progenies. In both 1952 and 1953, secondary seeds produced a lower final number of plants than did primary seeds but there was no significant difference in productivity of individual plants from the two seed sizes. Five lines selected from the 1953 progeny test were further purified in 1954 and 1955, resulting in lines exhibiting a great range of variability in vegetative characteristics and seed type.

More than 25 chemicals were tested in the field, greenhouse, and laboratory, for possible use for wild oat control, either as soil treatments or as foliage applications. Although some killing of non-germinated seeds occurred in laboratory tests involving direct application of herbicides to the seed, actual germination appeared to be prerequisite to effective chemical control under field conditions. Chemical-control methods thus do not appear to possess advantage over cultural-control methods where tillage can be used, and might be practical only where herbicides may relieve a growing-crop of wild oat competition or prevent production of viable wild oat seeds in a crop. The activity of herbicides exerting their effects through the soil varied, and depended upon

time of application and upon proximity of herbicide to germinating seeds, as influenced by precipitation and/or thoroughness of incorporation by tillage. Dalapon (dichloropropionic acid), IPC (isopropyl-n-phenyl carbamate), CIPC (chloro IPC), and CDAA (chlorodiallylacetamide) showed promise as pre-planting or pre-emergence herbicides, especially for use in crops tolerant to these chemicals. A tendency for flax to be ^{injured} was apparent at all stages of its growth, from rates of Dalapon as low as 1.5 lbs./A., while Argentine rape showed resistance to 3 lbs./A. of Dalapon when applied prior to emergence or up to nine days after emergence. As indicated by greenhouse tests, wheat and barley were much more resistant to CDAA than were wild oats, and emerged seedlings of these cereals were relatively unharmed by treatments with this chemical. Possible use of CDAA to protect established crops against later emerging wild oats may therefore be suggested. Success of this method would be dependent upon appropriate precipitation following application. Maleic hydrazide, Dalapon, and amino triazole were effective as foliage sprays on young wild oat seedlings, exerting their effects through stunting and suppression of heading rather than by eradication of the plants. Control of wild oats with chemicals such as maleic hydrazide applied to the weeds before the crop emerges is uncertain due to varying weather conditions, and cannot be favored over the cultural control practice of delayed seeding. Dalapon and amino triazole would be useful as foliage sprays only in crops which show adequate resistance to the residual toxicity exerted by these chemicals. Lasting wild oat seed-sterility induced by properly timed maleic hydrazide treatment of the flowering plants was found to result from an interference with normal embryo development.

Seeds maturing at widely different times on the same or different plants were not equally affected by a given single treatment of the plants with this chemical.

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PART I. NATURAL VARIABILITY OF THE WILD OAT

INTRODUCTION AND REVIEW OF THE LITERATURE

It is popularly conceded that wild oats cause Western Canadian farmers and farmers of the hard spring wheat areas of the North Western States more losses than are attributable to any other weed (13, 17, 25, 45). Friesen and MacKay (17) pointed out that wild oats are more prevalent in areas where growth of grain crops is favored, with the heaviest infestations found in regions characterized by parkland vegetation and black-colored soil zones. The series of years of favorable moisture supply which followed the drought years of the Thirties has favored the spread of this weed into areas where, formerly, it was not a problem. Coincident with this spread and increase in weediness due to climatic conditions, the advent of 2,4-D afforded relief from most of the troublesome broadleaved annuals and left the wild oat to stand out as one of the chief factors limiting profitable grain production.

Aside from burdening the farmer by competition with crops and increased costs of production, the wild oat has been responsible for great indirect losses because of the deviation from sound agronomic practices that control of the weed demands. Lowered yield from delayed seeding, greater susceptibility of late crops to disease epidemics, soil moisture losses and conditions conducive to erosion caused by extra tillage, the deplored practice of stubble burning, are but some of the prices of control measures not always

taken into account. Early shattering, delayed and irregular germination, low temperature requirements for optimum germination, and variable growth behavior depending on weather, soil, and cropping practices have made the problem of eradication difficult. The adoption, pursuit, and success in different areas of a given control program have been highly variable. Spectacular progress in chemical weed control has given rise to the hope that techniques of a simpler, more efficient, more dependable and economic nature may be worked out to supplement the older tillage control methods. In any case, the more that can be learned about variability of wild oats, the better should be the possibilities of establishing principles for more suitable and widely adaptable control measures.

Part I of the thesis is concerned with a study of "run of the field" wild oats originating on farms in various parts of Alberta and grown together under field conditions at Edmonton in 1952 and 1953. The progeny of selected plants representing extremes in variation observed in the 1952 experiment were also grown for study in 1953, 1954, and 1955. Most of literature on germination of wild oats concerns experiments under controlled laboratory conditions. There appears to be very little information on field comparisons carried beyond the seedling stage. In addition, most studies on the variability of wild oats appear to be concerned chiefly with the morphological characteristics of the seed rather than with the variation in vegetative habit of the plants. From the viewpoint of classification and of adaptation as a weed, the seed is of extreme importance. However, since it is

the plant which determines the competitive characteristics, variability in vegetative habit has received the most attention herein.

Many of the research findings and general observations applicable to tillage control methods have been recorded in extension publications of a non-technical nature (2, 3, 5, 13, 28, 29, 35, 36, 37, 39). The early scientific literature is concerned chiefly with the possible relation of wild oats to the origin of fatuoids in cultivated oats. Many of these studies have contributed to the understanding of the genetical basis for variability in appearance and behavior of wild oats (1, 18, 21, 31). Based on his own studies and those of other workers, Philp (31) stated that, "Avena sativa differs from A. fatua by a group of eight opposite factors (including those of the upper grain) which may be controlled by a complex of completely linked factors." The fatua type of basal articulation was found to be partially recessive to the sativa type, and factors for callus pubescence, rachilla pubescence, and strong awning were linked to those for the "suckermouth" basal articulation to form part of the fatua complex which distinguishes the species from A. sativa (1, 31). Malzew, as reviewed by Hector (19, p. 83), emphasized the close relationship between fatua and sativa by classifying them as subspecies of Avena fatua. Thus the botanical studies of cultivated oats contain a great deal that is applicable to wild oats and the reviews by Etheridge (16), Hector (19), Stanton (34), and others aid in the understanding of the weed species.

Superimposed on the fatua complex are the factors for length of callus hairs, hull color, and lemma pubescence which

determine the morphological variations used by Malzew, as reviewed recently by Lindsay (26), for classification of Avena fatua spp. fatua into varieties. Lindsay's paper includes information on the varietal distribution of wild oats throughout the prairie provinces and a key to their identification. His studies brought out the very great variation, not only in seed type but also in vegetative growth habit of the weed. Lindsay found natural hybrids between A. fatua and A. sativa and as a result of studies on the behavior of artificial intervarietal and interspecific crosses, stressed the possibility of a constant build up of physiological races, some even more perfectly adapted than their predecessors as weeds of the grain field.

Garber and Quisenberry (18) found delayed germination to be an inherited recessive character somewhat loosely linked to the fatua type of articulation. Johnson (21) worked out the inheritance of delayed germination in detail and found one of three factors influencing dormancy to be linked with the fatua complex. He explained the varying degrees of dormancy in segregation of progeny from A. fatua x A. sativa crosses on a multiple-factor basis.

Variability in the degree of dormancy possessed by different samples of wild oats has been extensively studied. In germination tests conducted over a period of years on freshly harvested seed from widely spaced locations, Lute (27) found one quarter of the samples to give below 10% germination while only one eighth gave over 80%. Her results suggested that less mature

samples are more dormant and remain in a dormant state for longer periods of time than do mature seeds. Toole and Coffman (43) reported wide differences in dormancy of seed obtained from ten localities throughout the western States but also reported wide variation between plants of any given locality. Their results did not point to noticeable differences in dormancy among samples of varying maturity or morphology. That environmental factors during seed formation may play an important part in the development of dormancy is suggested by the report of Bibbey (7) that samples of seed collected in two successive years from the same field at apparently the same stage of maturity differed by 90% in the proportion of readily germinable seed.

Johnson (20) obtained a progressive increase in the germinability of primary grains in passing from the lower to the upper, earlier maturing whorls but attributed more importance to ^{on the} position/panicle than to degree of maturity. Secondary seeds were found to possess a much more persistent period of non-germinability than the primary seeds. Johnson mentioned the survival value of this arrangement, whereby the seed of any given plant would provide propagules for at least two successive seasons. Chepil (14) observed that secondary seeds of wild oats did in fact persist longer than primary seeds under actual field conditions. Coffman and Stanton (15) found the longer period of delayed germination of the secondary seed as compared to the primary seed, to be general in all species and varieties of Avenae possessing some dormancy at the time of harvest.

The physiological basis of delayed germination in the wild oat was investigated more than forty years ago by Atwood (4). From the combined results obtained by breaking or searing the seed coat, or excising the embryo, from germination percentages obtained in varying concentrations of oxygen, and by direct measurement of the rate of oxygen uptake by intact or seared seeds or seeds in varying stages of after-ripening, Atwood concluded that oxygen was the limiting factor for germination of freshly harvested seeds. He believed that the after-ripening process consisted of a gradual change in the seed coat, rendering it more permeable to oxygen. Atwood noted an increasing acidity of the embryo and a rise in water holding power with after-ripening, which suggested that chemical alterations of the embryo may accompany the physical changes in the seed coat. Zade, as reviewed by Atwood, and tests by Atwood himself, showed that wild oat seed subjected to germinative conditions while still in the milk stage produced seedlings fairly readily. This finding suggested that ripening might tend to increase the impermeability of the seed coat. The investigations of A.J. Brown (8, 9) had shown that the seed coat of cereals can act as an almost perfect non-living, semi-permeable membrane, capable of excluding ^{most} salts and other substances in solution but freely admitting water. A.J. Brown's findings with barley and those of R. Brown (11) with wheat and oats, indicated that the semi-permeable system can be identified with the testa and the cuticle-like membranes on its inner and outer surface. The inner membrane, believed to be derived from the epidermis of the nucellus, appeared

to be the strongest barrier to the passage of solutes. Shull (33) found certain salts, notably nitrates, penetrated the seed coat of Xanthium at varying rates, but there was no evidence of the diffusion of oxygen, the lowered supply of which appears to limit the germination of this species as it does in the case of A. fatua.

Johnson (20) confirmed the results of Atwood, and by means of artificial crosses between A. fatua and A. sativa, with A. fatua as the female parent, demonstrated that delayed germination was due to a genetically controlled condition of the seed coat which developed after fertilization. The post-fertilization changes were thought to be related either to tissue absorption or development which occurred in the seed coat of A. fatua but not in readily germinable species, and the after-ripening processes to be due to gradual changes in the tissues of the seed coat resulting in increased permeability to oxygen. Johnson also showed that secondary dormancy could be induced by placing insufficiently after-ripened seed of wild oats under germinative conditions.

Opinion of many farmers to the contrary, the results of experiments and observations of many workers point to only a moderate period of longevity of the wild oat seed in the soil. As reported by Toole and Brown (44), the final results of the Duvel buried seed experiment begun in 1909, indicated that the seed of large seeded weeds and crop species did not tend to remain viable in the soil as long as did seeds of small seeded species. After one year of burial of wild oat seed at 8, 22, and 42 inches, Duvel obtained 9, 8, and 18 percent germination respectively, but no germination in the third year. Cates (13) stated that viability

did not exceed two years in poorly drained Red River Valley clay soils but persisted four to six years in well drained sandy loam soils. Chepil (11) placed the maximum period of dormancy at three to four years. In his fall sown experiments, 80% of the viable seed germinated during the first year, 18% during the second, 2% in the third, and only two seeds out of several thousand in the fourth year. Bibbey's data (7) indicated that most wild oat seeds showing primary dormancy after-ripened during the first winter and early spring, but seeds could be subjected to environmental dormancy when placed at depths where oxygen supply might limit germination. Results obtained at the Central Experimental Farm at Ottawa (12) showed survival of A. fatua seed for three years when buried at a depth of 18 inches. Thurston (42) reported a maximum period of survival of three years in pot experiments and slightly longer in the field. Thurston obtained no evidence of secondary dormancy having been induced by deep burial. Her results showed emergence of fresh seed from depths as great as nine inches but noted a marked decline in vigor when seed had lain in the soil for long periods before germinating.

Survival of wild oat seed under grassland conditions may possibly be somewhat longer than in frequently disturbed soil. Perennial forage crops can be expected to keep the soil drier throughout the infested layers for longer periods of time, thus favoring longer seed life than would be the case with annual crops in a rotation including summerfallow. Thurston (42) cited an example of wild oat seeds having survived for four years in

undisturbed grassland soil. The studies of Brown (10) with long term rotations have shown survival of wild oats in grassland after four or five years, thus making delayed seeding advisable the first crop season after breaking. Many farmers in western Canada have claimed serious infestation still existed after soil was in grassland for periods up to ten years. Since there are many ways in which fresh seed could continue to be introduced, through grazing, by machinery, or the incidental plant maturing unnoticed, it is possible that in many cases, wild oat growth after breaking should not be attributed to seed actually present when the grass crop was established. There would appear to be a need for additional well authenticated information on the longevity of wild oat seed under different cropping practices.

Although subject to many of the diseases of cultivated oats, wild oats do not appear to be seriously limited in productivity by disease or insect pests. Suneson (38) found that although wild oats in California were regarded as a carrier of rust through the winter months, some plants had resistance to both crown and stem rusts of oats. Five selections were found to have resistance to certain races of crown rust, and there were indications that the genetical basis for this resistance was not the same for all five selections. Thurston (41) compared the growth of wild and cultivated oats in manganese deficient soils. A. fatua was judged less susceptible to grey speck disease than the cultivated varieties used and showed a smaller reduction in the number of seeds formed, but a greater reduction in size and Mg content of individual seeds.

Manganese deficiency lowered the percentage of viable seeds and the percentage of dormant seeds of A. fatua.

Kirk and Pavlychenko (24) found ready vegetative regrowth from the nodes to be a factor influencing the success of tillage under different soil moisture conditions, and pointed to the necessity of waiting until two or more leaves had formed before attempting to destroy growth by cultivation. The studies of Bibbey (6) and of Brown (10) have provided a great deal of information on the value of various tillage and cropping practices in promoting germination and in control of wild oats. Bibbey noted that cereals planted as early in the spring as possible, emerged five to nine days ahead of wild oats from natural infestations. Pavlychenko and Harrington (30) studied the competitive efficiency of wild oats and various cereals throughout their growing periods. In the seedling stage and up to 22 days after emergence, wild oats with slower and less uniform germination, and an inherent number of only three seminal roots, were at a marked disadvantage to the cereals, notably barley. Following the establishment of secondary roots, the wild oat root system soon surpassed that of the cereals. Above ground manifestation of competitive ability, such as size of assimilation surface of leaves, further indicated that unless a crop was well established and ahead of wild oat growth at the seedling stage, there was little hope of effective competition later.

EXPERIMENTAL

Section A. Studies on wild oat plants from seed obtained from various locations in Alberta

MATERIALS AND METHODS

Nine samples of grain containing wild oats, from the 1951 crop grown under various soil and climatic conditions, were supplied by representatives of the Alberta Department of Agriculture. From the mixed population of wild oat seed from each location, only fully mature, fully pigmented kernels were selected for study and these were sub-divided into "small" and "large" kernels from each place. Since the wild oat spikelet consists of 2-3 florets producing primary, secondary, and often tertiary kernels whose size diminishes in that order, the bulk of the "small" kernels were probably secondary kernels while the "large" seeds for the most part would arise from the primary florets of the wild oat spikelet. "Small" seeds averaged 15.1 grams per 1000 kernels, and "large" seeds 25.9 grams per 1000 kernels.

On May 16, 1952, 100 seeds of each sample were sown in single-row-plots 25 feet long and 18 inches apart in a randomized block design replicated four times. One year later, on May 20, 1953 the experiment was repeated using wild oat seed from the original 1951 stock, the after-ripening process of which could be expected to be more advanced due to the additional year of dry storage at room temperature in the laboratory. In 1953 the

experimental design differed in that 50 seeds were used in single row plots spaced two feet apart but separated by a buffer strip of Kharkov winter wheat. The buffer strips were added to provide a uniform amount of competition for each row and to overcome any border effect which might arise as a result of plants from a low germinating source lying next to a high germinating source or vice-versa.

Detailed records of percentage emergence were taken in both years at short intervals during the seedling stage and near the time of plant maturity. Periodic observations on heading were made during July. The final number of tillers per plant was recorded 115 days after planting in 1952, and the number of tillers and of panicles was counted 100 days after planting in 1953.

EXPERIMENTAL RESULTS

(a) Emergence and survival of wild oat plants

Table I is a summary of the 1952 and 1953 data for (1) emergence and survival, and (2) tillering and heading of wild oat plants, grown at Edmonton. Fig. 1 is an example of the appearance of plants representing several locations, at 56 days after planting in 1952.



Fig. 1. Variability in wild oat plants 56 days after planting in 1952. The center plot, from Moon Lake "small" seeds is an example of extremely slow development. Plots to right and left of center consist of plants from large or small seeds from other locations.

Table I. Variability of wild oats from seed of various sources planted at Edmonton May 16, 1952, and May 20, 1953. (Means of 4 replicates except for tiller and panicle data of 1953 which are the means of 3 replicates.)

Days after Planting			11	14	16	23	100	11	14	16	23	100	113	73	100	100		
			1000 Kernel Wt. (grams) of seed planted 1952															
Seed Source and Size			% Emergence and Stand 1952				% Emergence and Stand 1953				Tillers per Plant		Panicles 1952		Tillers /Plant		Panicles 1953	
1.	Didsbury	large	28.9	4	20	43	67	59	58	66	70	76	68	17.4	4.1	17.0	12.6	
2.	"	small	19.9	12	31	44	58	50	60	72	74	74	67	17.6	3.7	14.9	10.7	
3.	Drumheller	large	29.0	4	23	40	58	53	70	76	74	76	62	16.9	2.7	14.8	11.3	
4.	"	small	19.5	6	21	35	58	47	66	76	78	82	63	17.5	2.4	14.1	9.8	
5.	Berwyn	large	22.3	8	35	54	80	58	50	68	70	72	64	17.7	1.5	11.8	8.2	
6.	"	small	13.0	12	33	48	70	52	43	54	60	63	57	15.6	2.0	12.4	9.5	
7.	Iacombe	large	22.1	5	16	31	52	43	49	56	57	56	48	16.9	1.0	14.6	10.2	
8.	"	small	15.0	5	13	18	28	25	40	46	46	46	39	20.4	0.9	15.2	10.8	
9.	Athabasca	large	29.2	11	39	50	68	57	68	77	79	78	62	16.8	2.8	19.5	12.7	
10.	"	small	16.0	4	18	33	43	36	62	70	70	74	67	18.3	1.8	15.1	10.2	
11.	Moon Lake	large	23.0	5	20	36	62	54	30	38	44	44	42	17.7	2.4	17.9	11.3	
12.	"	small	9.4	1	8	13	30	35	20	28	28	29	30	18.6	1.0	14.1	9.8	
13.	Evansburg	large	25.9	14	37	53	69	53	53	60	62	60	51	16.7	3.0	16.2	11.0	
14.	"	small	11.6	3	14	24	32	30	32	36	37	40	36	20.2	1.6	16.3	11.8	
15.	Edmonton	large	26.5	4	14	24	37	34	61	68	69	74	62	18.2	1.9	14.1	9.7	
16.	"	small	15.3	1	4	9	15	20	58	65	64	64	59	22.4	1.0	16.4	10.5	
17.	Wainwright	large	26.5	11	31	48	52	52	64	74	76	85	78	19.8	2.4	18.4	11.1	
18.	"	small	15.8	4	18	29	36	33	68	80	82	84	69	21.5	1.7	14.1	10.0	
Experiment	large	25.9	7.3	26.1	42.1	61.7	51.3	55.9	64.8	66.4	69.0	59.6	17.6	2.4	16.0	10.9		
Means:	small	15.1	5.3	17.8	27.9	41.5	36.4	49.9	58.6	60.0	61.9	54.1	19.1	1.8	14.7	10.4		
L.S.D.'s @ 5% level		1.0			12.0	9.3	8.7			13.1	9.5	9.0	No Signif. Differences	0.9	3.1	2.2		

Some very significant differences between sources of seed and between the results from the two years are manifest in the data of Table I. It can be seen that:

1. Emergence of seedlings was much slower in 1952 than in 1953. On the day of first emergence in 1952 (11 days after seeding in both years) the experiment mean was only 7.3% for large seeds and 5.3% for small seeds, contrasted with an experiment mean of 50% or more in 1953 for both large and small seeds. Maximum germination did not occur until the twenty-third day in 1952, whereas a levelling off of new emergence occurred at about sixteen days in 1953. Taking emergence at twenty-three days as the maximum for both years it is seen that, depending on the seed source, the additional year of dry storage, with only two exceptions, led to a 8%-49% higher emergence from small seeds. The two exceptions were Berwyn and Moon Lake small seeds, the emergence of which dropped slightly in 1953. It is of interest that small seeds of Berwyn had a rather high percentage emergence in 1952, while "Moon Lake small" showed pronounced dormancy in that year. On the whole, additional dry storage was also followed by greater emergence, ranging from 4%-37% increase in plants from large seeds. Decreased emergence occurred after the additional year of dry storage of large seeds from only three locations, Berwyn, Moon Lake and Evansburg. Since a difference of just over 9% was necessary for statistical significance in variation between samples in both years, many of the smaller increases or decreases in germinability between years might not be expected to be significant.

2. The thousand-kernel-weight of the samples planted in 1952, as recorded in column 1 of Table 1, show the very great variation in seed size between threshed, mature seed from the various locations. The thousand-kernel-weight of the large seed varied between 22.1 and 29.2 grams while thousand-kernel-weight of small seed varied between 9.4 and 19.9 grams. The coefficient of correlation between seed weight and percentage emergence at 23 days after planting was only 0.087 for the large seeds and 0.382 for the small seeds, showing that seed weight was not a factor in determining readiness of germination.

3. In both 1952 and 1953, a decline in number of plants occurred between the time of maximum emergence at 23 days and the final count of maturing plants at 100 days after seeding. This decline has been attributed to natural causes such as insect and disease mortality, mechanical injury, etc. It might also be expected that late emerging seedlings would tend to be weak and have less survival value, especially in 1952 where initial establishment of stand was slower than in 1953. Depending on the source of seed, as little as 41%, to as much as 80% of the planted material, had not resulted in mature plants in 1952. In 1953, from 22% to 70% of the planted material had not resulted in mature plants 100 days after planting.

4. Analysis of data on emergence and survival at 16, 23, and 100 days after planting for both 1952 and 1953, showed that in all cases the large seeds germinated better than the small seeds. Within sources of seeds in 1952, large kernels produced significantly more mature plants than small kernels in seven of the nine pairs of such

samples. Only small seeds from Drumheller and Berwyn produced stands statistically equal to stands from the large seeds. Final stands in 1953 showed survival counts of plants from the small seeds to have increased to the extent that only with the seeds from Moon Lake and Evansburg, was a significantly greater stand produced by large seeds as compared to the small. The experiment means given in Table I for the large and the small seeds, indicate that there was a considerable increase in germination and final stand of all wild oat seed with additional storage. Breakage of dormancy was greatest for the small wild oat seeds thus resulting in reduction of differences between the two classes of seed size accompanying elapsed storage time.

5. Between sources of seed in 1952, only two samples of large seed (Lacombe, Edmonton) gave results significantly different from those of large seeds from the other seven locations. In 1953 the large seeds from Lacombe retained their low potential while the large seeds from the Edmonton source almost doubled the number of surviving plants produced. Samples of large seeds from Wainwright rose from production of an average stand in 1952 to yield the greatest number of plants in 1953, while conversely, Moon Lake large seeds dropped from giving an above average stand of 54% to the lowest stand, 42% after additional storage. Large seeds from other stations such as Didsbury and Berwyn appeared to retain approximately their same relative rank throughout the two year period.

6. Between sources, the large seeds could be split into only two distinct classes of relatively high and medium growth potential. The small seeds from various sources, however, could be arranged

into low, medium, and high classes of stand grouped around the experiment mean of 36.4% at 100 days after seeding in 1952. This indicated greater variability between sources for the small seeds than for the large seeds which was again borne out in the 1953 results where the three classes of final stand for the small seeds were grouped around an experiment mean of 54.1% and ranged from a high of 69% to a low of 30% of potential stand at maturity. It is interesting to note that the small seeds of many sources exhibited a pattern similar to the large seeds of that source as regards change in rank of potential productivity after additional storage. Small seeds of Lacombe, Edmonton, Wainwright and Didsbury, for example, behaved as described above for the large seeds of these sources.

7. In 1952, large kernels from only one source, Edmonton, were clearly surpassed by small kernels from three sources, Berwyn, Didsbury, and Drumheller. In 1953, the large seeds of Moon Lake, whose growth potential had dropped, and those of Lacombe, which had probably not changed significantly, were surpassed by all small kernel samples which could be placed in the intermediate and high classes. Small seed from only three sources, Lacombe, Evansburg, and Moon Lake produced as poor a stand as did the two sources of large seed referred to above.

(b) Tillering and heading

The results for tillering and heading appear to justify the following observations:

1. Although the differences between the mean number of tillers per plant for the different sources were ^{not} significant in 1952, there appeared, however, to be a trend towards higher numbers of tillers with the reduced stand associated with small seeds. Small seeds produced an experiment mean of 19.1 tillers per plant contrasted with 17.6 for the large seeds, and small seeds from all sources except Berwyn produced slightly more tillers per plant than large seeds. That this trend was real was supported by a correlation coefficient of -0.77 between percentage stand at 100 days and number of tillers per plant as determined at 113 days. In 1953, the value of the buffer strips of winter wheat used to provide uniform competition became apparent since the correlation coefficient between stand and tiller production was only 0.06. Apparently the competition from uniform buffer strips allowed inherent tendencies for tiller production by the various seed sources to be more freely expressed. Among the seed sources and sizes in 1953, variation in the number of tillers per plant was highly significant, with large seeds producing significantly more tillers than small seeds within three sources, Athabasca, Moon Lake and Wainwright. Large seeds from Athabasca produced significantly more tillers per plant than the large seed mean of 16.0, while "Berwyn large" produced less than the mean. The smaller number of tillers per plant in 1953 as compared to 1952 may be attributed to the more severe overall competition and to the tillers having been counted thirteen days earlier in 1953. At 100 days after planting in 1953 there were many small tiller buds capable of producing late tillers.

2. In 1952 there were highly significant differences between the mean numbers of panicles per plant when counted at 73 days after planting. At this time only about 11 days had elapsed since the beginning of general heading and there was no positive correlation between the final number of tillers per plant and the number of panicles which had emerged. Since difference in tiller number was not significant, panicle numbers could be taken as a measure of the relative earliness of wild oat plants from the various samples. Such differences could have been caused, in part, by variation in the rates of emergence of the plants, resulting in unequal growing periods. Inspection of the emergence data, however, leads to the conclusion that some samples matured more rapidly than others. For example, No. 1, "Didsbury large" had the greatest number of panicles per plant (4.1) and comparison with significantly different No. 5, "Berwyn large" (1.5), or with No. 17, "Wainwright large" (2.4), shows that if anything, the Didsbury sample emerged more slowly than did the other two. Moreover, there were no significant differences between final percentages for stand of these samples. "Lacombe large" can be taken as having the latest maturity. The number of panicles produced at 73 days was significantly less than the experiment mean of 2.4 panicles per plant. Didsbury and Lacombe ranked first, and last, respectively, as regards number of panicles per plant grown from large seeds. It is of significance that there was an exact parallel in the behavior of small seeds from the two locations. That is to say, the potential for panicle production showed a strong relationship to conditions of origin regardless of seed size. The significant difference in panicle production between plants from large and small seeds from Athabasca, Moon Lake, and

Evansburg, which occurred in 1952 may perhaps be more correctly attributed to delay in seedling establishment than to natural differences in maturity between plants produced from different seed sizes.

3. Significant differences between mean number of panicles per plant also occurred in 1953, when panicles were counted at 100 days after planting, but a significant difference in tiller numbers, coupled with a correlation coefficient of 0.85 between tiller and panicle numbers, rendered panicle counts taken at this later date unreliable for establishing relative earliness. However, between the years a pattern of behavior could be noted as regards panicle production of an individual seed lot. In 1953, panicle production from Didsbury seed remained high, second in rank for the large seeds, and third in rank for the small seeds. "Berwyn large" remained low in panicle production while "Wainwright large" and "small" maintained their position as producers of an average number of panicles per plant. In panicle production, as in other characters previously mentioned, plants from large seeds were less variable between the years than were plants from small seeds.

(c) Vegetative characteristics

In addition to the very great differences in emergence and stand, tillering and heading, exhibited under uniform conditions by plants from the various seed sources, a wide range of visual growth characteristics could be observed among plants from the various sources, and also among individual plants of the single-row-plots.

It was evident that the wild oat samples from most sources represented a very mixed population making it difficult to characterize the growth habit of plants of a given source unless they represented an extreme. Observations in 1953 placed Didsbury seeds as producers of the earliest plants, followed by Evansburg seeds, while plants of Berwyn, Lacombe, and Moon Lake origin tended to be late. Plants varied in having erect or spreading tillering habits. In general, plants from Drumheller seed tended to be short, while Lacombe, Edmonton, and Wainwright plants were tall. A waxy blue-grey bloom on the sheath, lamina, and glumes, particularly noticeable after the shot blade stage, imparted a deep glaucous-green to some plants while other plants had little bloom and were yellowish-green in foliar appearance. Only plants from Lacombe seed appeared to be pure for the glaucous character, other seed sources produced plants of mixed foliage color, either yellowish or glaucous. Marked differences in color and pubescence of mature seeds occurred between the samples and between individual plants from seed samples. Two diseases, blast of oats and bacterial stripe blight of oats were very evident and appeared to vary in intensity between plots according to sample sources.

SUMMARY OF RESULTS AND CONCLUSIONS FOR SECTION A

Samples of grain containing wild oat seed from the 1951 crop were obtained from nine widely separated locations throughout the province of Alberta. Sub-samples of large and of small wild oat seed were planted at Edmonton in May 1952 and 1953 for observations on emergence and development under uniform conditions.

Although initial emergence in both years occurred at 11 days after seeding, maximum emergence was not attained until 23 days in 1952, whereas emergence in 1953 levelled off at 16 days. This illustrates one of the difficulties experienced in different years or under different conditions of location in predicting the behavior of a natural farm infestation at seeding time.

In 1952, large seed from seven of the nine locations produced significantly more mature plants than did the corresponding small seeds. An additional year of dry storage of seed in the laboratory resulted in a marked decrease in dormancy of seed from most sources, especially among small seeds. The result was that, in 1953 large seeds from only two sources produced a significantly greater stand than did the small seeds, although for the experiment as a whole, small seeds still produced stands significantly inferior to those of large seeds. In spite of a net increase in germinability throughout the experiment, both large and small seeds from two sources showed a slight decrease in vitality after a second year of storage.

Between sources in both years, large seeds could be placed into distinct classes of relatively high and of medium potential stand while small seeds from the various sources could be arranged into three classes corresponding to low, medium and high potential. The small seeds of many sources followed a pattern similar to the large seeds of corresponding sources as regards change in rank of potential productivity with additional storage.

There were no significant differences between the numbers of tillers per plant between samples in 1952. This fact coupled with significant differences in numbers of panicles per plant visible shortly after the beginning of heading revealed differences in earliness of maturation among some of the samples. Early heading observations in 1953 confirmed these results.

Plants of the various samples, and individual plants of a sample, varied in having: erect to spreading tillering habit, tall to short growth habit, varying amounts of glaucous bloom on the foliage, marked differences in color and pubescence of seed, and differences in prevalence of disease. It was evident that the wild oat seed samples from most sources represented a very mixed population. This fact, representative of general conditions in the prevalence of wild oats on farms, obviously complicates the problem of developing standard control measures for this weed.

Section B. Studies on progeny from individual wild oat plants

MATERIALS AND METHODS

In order to study more precisely the variability shown in 1952 among individual wild oat plants from the various sources, the mature panicles of 25 plants grown in the single row plots for two of the seed sources, Didsbury and Moon Lake, were kept separate for experiments with progeny of individual plants in 1953. Didsbury seed sown in 1952 was characterized by good emergence of plants

from both large and small seeds and by highest rank in earliness and number of panicles for plants from the nine seed sources. Moon Lake seed sown in 1952, showed good emergence of plants from large seeds but poor emergence, later maturity, and below average panicle production of plants from small seeds.

The experimental design used with the 1953 progeny test was limited to three replicates and to 20 primary seeds and 20 secondary seeds per pair of single row plots by the small number of mature seeds available from some of the plants from 1952. Enough seed was obtained from 44 plants, 22 from each source. The Didsbury progeny were identified with the plant numbers, 1-1, 1-2, 1-3, ..., 1-22; and the Moon Lake progeny were numbered, 12-1, 12-2, 12-3, ..., 12-22. Seeds from each individual plant were sown in two row whole plots with primary and secondary seeds planted in single rows side by side as split plots. In one case, additional seed types as noted below were included from high yielding plant number 12-4 and randomized as extra split plots within the respective whole plot. In this way plant number 12-4 was intended to facilitate comparison of the behavior of mature tertiary, and immature primary, secondary, and tertiary seed as well as that of mature primary and secondary seed. The seeding was done on May 20, 1953 in rod row plots spaced two feet apart and separated by a buffer strip of Kharkov winter wheat.

Emergence records were taken at short intervals during the seedling stage and counts were made on final stand, tillers and panicles 108 days after seeding. Didsbury and Moon Lake progeny

were analysed separately and replicate totals for primary and secondary seeds of each were analysed for differences between progeny of the two sources.

RESULTS AND DISCUSSION

(a) Final stand of wild oat plants

First emergence of wild oat seedlings occurred eleven days after planting and maximum emergence in most cases was complete five days later, at sixteen days after seeding. A small decrease in stand was noted at the end of the season. The percentage for final stand was used in studying the relative potentials of the different progeny. Table II gives the percentage final stand of plants from the primary and secondary kernels, the combined stand as a percent stand from all seeds of each progeny, and the combined mean number of tillers and panicles of both seed types of a progeny.

The original Didsbury seeds planted in 1952 gave a relatively good stand from both large and small seeds, 59% and 50% respectively. The seed of the 22 plants from this source grown in 1953 showed a highly significant difference in stand between primary and secondary seeds. A highly significant interaction between plants and seed size, however, indicated that the secondary seeds from individual plants did not always show weaker germination than the primary. From Table II, it may be seen that seed size of plants 1-16, 1-18, and 1-19, did not influence percent germination to as large a degree as did seed size of most of

Table II. Variability between progeny of single wild oat plants grown at Edmonton in 1952 from "Didsbury large" and "Moon Lake small" seeds. Data obtained 108 days after seeding May 20, 1953. \bar{M} of 3 replicates.

Didsbury progeny number	% Finald Stand			Mean Numbers of: Tillers Panicles /plant /plant			Moon Lake progeny number	% Final Stand			Mean Numbers of: Tillers Panicles /plant /plant		
	Primary	Secondary	combined	P & S	combined	P & S		Primary	Secondary	combined	P & S	combined	P & S
1-1	78	22		50	22.4	14.7	12-1	66	45	56	16.6	9.9	
1-2	55	5		30	19.6	15.4	12-2	50	30	40	23.2	15.7	
1-3	76	12		44	22.9	16.2	12-3	76	63	70	16.0	9.4	
1-4	70	52		61	19.8	15.8	12-4	70	42	56	20.7	18.7	
1-5	52	18		35	29.1	24.2	12-5	63	46	55	21.0	14.9	
1-6	58	5		32	22.7	17.2	12-6	66	35	51	21.1	14.0	
1-7	58	20		39	15.8	12.1	12-7	75	42	58	22.2	13.2	
1-8	52	8		30	23.0	17.4	12-8	68	45	57	30.4	16.9	
1-9	60	43		52	13.1	12.7	12-9	66	13	40	19.0	11.5	
1-10	43	38		40	17.3	13.4	12-10	66	20	43	21.2	15.4	
1-11	61	22		42	21.8	15.5	12-11	63	40	52	16.2	11.6	
1-12	70	17		43	19.6	14.1	12-12	43	15	29	24.2	15.9	
1-13	80	18		49	24.4	16.7	12-13	78	45	62	13.0	10.6	
1-14	76	10		43	17.7	13.4	12-14	61	32	47	22.5	16.1	
1-15	65	17		41	18.3	14.4	12-15	46	22	34	17.9	12.6	
1-16	68	52		60	20.8	14.0	12-16	71	30	51	14.5	11.1	
1-17	76	43		60	15.8	11.8	12-17	42	13	28	31.6	19.1	
1-18	68	60		64	22.0	16.7	12-18	85	66	76	14.2	9.8	
1-19	65	73		69	20.2	16.0	12-19	45	7	26	34.6	17.7	
1-20	78	7		42	25.0	19.7	12-20	60	53	57	15.2	10.0	
1-21	85	43		64	21.1	15.0	12-21	55	42	48	20.1	16.2	
1-22	86	48		68	15.8	12.2	12-22	66	36	52	18.9	13.9	
Experiment means	67	29		48	20.4	15.3		63	36	49	20.7	13.8	
ISD's @ 5%				10.7	7.0	5.9				10.0	6.9	4.8	

the other plants. There was a considerable variation between plants, with the seed of four plants giving a significantly lower percentage stand than the experiment mean for Didsbury progeny, while the seed of seven other plants produced a larger stand than the mean.

The original Moon Lake seeds planted in 1952 gave a relatively good stand from large seeds but a poor stand from small seeds. The primary and secondary seeds of the 22 plants from this source, sown in 1953, showed a highly significant difference in growth potential, while an insignificant interaction between plants and seed size indicated consistent higher germination of the primary seeds. Differences between plants were highly significant with the seed of four plants producing a smaller stand than the mean of all Moon Lake progeny while the seed of three other plants produced a larger stand. Analysis of replicate totals for the two progeny sources showed no significant gross differences between stands of plants from the two sources.

(b) Tillering and heading

Analysis of overall data for tiller and panicle counts taken at 108 days after seeding showed no significant differences between the two progeny sources. Within the progeny sources, there were no significant differences in production of tillers or of panicles by plants from primary and secondary seeds, nor were interactions for seed size vs. progeny significant. Tiller and panicle production differed significantly, however, within the 22 plant progenies of Didsbury origin and differences were highly significant

within the 22 plant progenies of Moon Lake origin. Among the Didsbury progeny, seed of plant number 1-9, produced plants with fewer tillers than the Didsbury progeny mean of 20.4 tillers per plant, and progeny of plant 1-5, produced a greater number of tillers than the mean. Seed of Moon Lake plant 12-13, produced plants with fewer tillers than the mean, and progeny of plants 12-8, 12-17, and 12-19 produced more tillers than the Moon Lake mean of 20.7 tillers per plant.

Differences between the mean number of panicles on the almost mature plants were significant but conditioned by the variation in tiller number. Plants producing the largest number of tillers invariably produced the largest number of panicles.

(c) Vegetative characteristics

Variations in growth habit observed in the preceding experiments of Section A, with mixed populations of seed from nine sources, were also very evident among the 22 single plant progenies of both Didsbury and Moon Lake plants. Less variation of course existed within these plots than in those representing the mixed population since each 1953 plot contained only plants constituting a single line of the predominantly self-fertilized species. From observations made at early heading time, 55-60 days after seeding, the progeny of fourteen Didsbury plants were classed as early, and only five classed as late in heading. The Moon Lake plant rows consisted of a greater proportion of late heading lines, with only

nine classed as early heading and nine classed as late heading. Great differences in height existed between rows but height was usually fairly uniform in plants within rows. Color and pubescence of mature seeds produced by plants within plots appeared uniform.

No Didsbury row showed more than a trace of blast, while Moon Lake progeny rows from seed of plants 12-2, 12-3, 12-8, and 12-22 were very heavily blasted. Most of the single progeny rows throughout the experiment contained plants infected with bacterial stripe blight of oats. However, four individual plant progenies, 1-5, 12-2, 12-8, and 12-22, appeared to be resistant to the disease in all six rows of each progeny (2 seed sizes x 3 replicates). In addition, five Didsbury progeny and six Moon Lake progeny showed blighted plants in one row only. The buffer strips of winter wheat had formed a dense, moisture-holding, cover at the base of the wild oat plants, causing conditions conducive to the spread of bacterial disease.

Progeny rows were either glaucous-green in foliar color due to the presence of a waxy bloom, yellowish-green in the absence of the bloom, or contained plants with both foliage color within a row. Eleven Didsbury plant progenies were pure for glaucous foliage color and only three progenies were pure for the yellowish foliage color. Only six Moon Lake progenies were pure for glaucous foliage color but eight were pure for yellowish-green foliage color. Eight of the 22 single plant progenies of both Didsbury and Moon Lake origin appeared to be heterozygous for foliage color with individual

plants within a progeny row either of glaucous or yellowish-green color. The high number of progeny impure for this character and the varying proportions of this mixture suggested a process of segregation such as would occur from natural crosses, and could contribute much to the variability of the weed. Variation in other characteristics not as readily detectable as a morphological characteristic, such as inherent dormancy and earliness of seed shattering, can also be expected as a result of outcrossing.

(d) Behavior of tertiary and immature seeds

Referring to the data in Table III, it may be seen that a far greater spread existed between the growth potential of tertiary seed, compared with secondary seed, than between that of secondary and primary seed. Immature seed of all three seed classes gave a

Table III. Relative productivity of mature and immature, primary, secondary and tertiary wild oat kernels. (From plant 12-4, sown May 20, 1953, after storage since the previous fall.)

	<u>% Final Stand</u>	<u>Tillers/Plant</u>	<u>Panicles/Plant</u>
<u>Mature Seed</u>			
primary	70	20.6	15.9
secondary	42	25.0	18.3
tertiary	17	19.8	15.6
<u>Immature Seed</u>			
primary	52	19.6	14.7
secondary	38	17.7	13.2
tertiary *	15	13.0	9.3

* Tertiary immature - 1 replicate only, all other data the mean of 3 replicates, 20 seeds per single row plot.

poorer stand than mature seed of the same classes. Observations on early emergence showed that immature seed and tertiary seed were much slower in establishing a stand, resulting in less vigorous growth throughout the season and decreased numbers of tillers and panicles per plant at 108 days after seeding. It might be expected that a vigorous crop growth could effectively compete with and smother wild oat plants from weaker seeds of this sort. Hector (19, p. 100) stated that seed size was one of the factors influencing the tillering capacity of wheat. From the results shown in Table III and from a comparison of tillering and heading of plants from primary and secondary seeds, it may be concluded that seed size was not a factor influencing tillering capacity of wild oats unless the seed was very small, as in the case of tertiary seed, or unless the seed was immature.

Section C. Studies with purified lines of wild oats

MATERIALS AND METHODS

For further study of single progeny lines of wild oats in 1954 and 1955, five lines exhibiting very different characteristics were selected from the 1953 progeny test. They represented extremes in variation of plant types observed in the studies of Section B. Lines were selected for agronomic characteristics such as, height of plants, erect or spreading tillering habit, color of foliage, disease reaction, and seed type.

The five lines were from the seed of plants which had been designated as 1-18, 12-2, 12-3, 12-8, and 12-21. Since considerable information had already been obtained on the differences in behavior of primary and secondary seeds from the experiments of Sections A and B, only mature primary seeds were sown in 1954 and 1955. To determine the purity of the lines, seeds of three plants per line were grown in 1954 in single plant progeny rod-row plots as split plots, two feet apart separated by a buffer row of Thatcher wheat. The experiment was seeded May 18, 1954 using four replicates and 25 seeds per single row plot. Harvest was delayed until 118 days after planting, at which time percentage mature stand, and tiller and panicle numbers were determined. Seed from the center row of each of the five whole plots of replicate I was bulked and stored in the laboratory for sowing in 1955. The five lines were sown again May 11, 1955 using three row plots of rod length, spaced one foot apart and containing 50 seeds per row. The plots were separated by a buffer strip of Thatcher wheat. At harvest 96 days after planting, tiller and panicle counts were made on ten plants from the center row of each plot. Yield in lbs./acre was determined from the bulked seed of each three row plot. In order to check the progress of after-ripening, laboratory germination tests were conducted at intervals following harvest.

In addition to germination tests, a comparative study was made of the early growth of seedlings from primary and secondary seeds of the five wild oat lines and of A. sativa var. Victory.

The rate of absorption through the seed coat and staining of the embryo by 2,3,5-triphenyltetrazoleum chloride was plotted for various samples of oats in an effort to shed further light on the role of the seed coat as associated with after-ripening and on the artificial induction of secondary dormancy. Experimental procedure used in the above laboratory tests will be discussed later, under sub-section (d).

RESULTS AND DISCUSSION

Table IV gives the data for emergence and development of plants from primary seeds of the five lines for the three year period in which they were grown. The 1953 data are an excerpt from the progeny test recorded in Section B. The usefulness of the 1954 data was limited by an unfortunate placing of part of the experiment on sterile ground which was afterwards learned to have been the site of a chemical bath for sheep. Parts of three replicates were involved in the area, necessitating discarding nine out of the twenty whole plots.

(a) Emergence and final stand

First emergence occurred on the eleventh day after planting in 1953, and on the twelfth day in 1954 and 1955. Maximum emergence was reached at about 16 days in 1953, and at about 19 days in 1955. Although the maximum percentage emergence varied from 64%-80% in 1955, there was no significant difference between wild oat lines. Over the three year period, however, line 12-3 tended to have the

Table IV. Emergence and development behavior of five lines of wild oats over a three year period. Harvest data obtained at 108, 118, and 96 days after planting for 1953, 1954, and 1955 respectively.

Date planted	Line number	Maximum % emergence	% Stand at harvest	Tillers per plant	Panicles per plant	% Tillers headed	Height (in cm. where given)	
May 20	1-18	73	68	19.0	15.1	79	tall	
<u>1953</u>	12-2	57	50	24.2	17.1	71	medium	
	12-3	80	76	16.5	9.8	62	tall	
	12-8	75	68	30.9	17.5	57	short	
	12-21	55	55	19.8	16.5	83	short	
May 18	1-18	80	66	12.8	8.6	67	159	
<u>1954</u>	12-2	76	63	12.6	8.9	71	153	
	12-3	83	69	11.3	6.5	58	173	
	12-8	71	63	25.0	12.6	50	142	
	12-21	84	72	12.1	10.1	83	132	
								Yield lbs./acre
May 11	1-18	80	-	14.6	9.7	68	119	640
<u>1955</u>	12-2	68	-	20.0	12.5	64	114	1083
	12-3	70	-	12.8	9.1	71	137	814
	12-8	68	-	28.1	16.3	58	107	1026
	12-21	64	-	19.7	13.6	69	98	1037
L.S.D. @ 5%		*		3.8	3.1	*	3.0	103

* No significant differences.

highest germination, placing either first or second in emergence among the five lines. Line 12-21 placed lowest in emergence in two years but was highly germinable in 1954. Recorded final percentages for stand coincided with the pattern shown by figures for maximum emergence.

(b) Tillering, heading and yield

Highly significant differences in inherent tillering capacity occurred between strains in 1955. Over the three year period line 12-3 consistently produced the lowest number of tillers per plant and line 12-8 consistently produced the highest number of tillers per plant. The other three lines which produced an intermediate number of tillers were consistent in rank during 1953 and 1955 but varied somewhat in rank in 1954. Panicle production among the five lines was highly correlated with tiller numbers in all years. Line 12-3 with the lowest tillering capacity produced the least number of panicles, and line 12-8 with the highest tillering capacity produced the greatest number of panicles. The percentage of tillers which had headed at dates of harvest are given in column five of Table IV. It is seen that although strain 12-8 ranked highest in number of panicles per plant in all years, its actual percentage of tillers bearing panicles was smallest among the five lines. In 1955, the exact opposite relationship occurred with line 12-3. Line 12-3 produced the smallest number of tillers and panicles but the percentage of headed tillers at 96 days was the greatest for the five lines. Thus extreme tillering tended to result in unevenness of maturation with a resultant extension of the period in which seeds on an undisturbed plant could continue to ripen and shatter.

In 1955, commencement of heading took place at 54-59 days after planting. Lines 1-18, 12-3, and 12-21 were classed as early heading, line 12-8 as intermediate, and line 12-3 as late heading.

Early anthesis took place 3-4 days after first heading and the top-most spikelets of early panicles commenced shattering about 18 days after first heading (72-77 days from date of planting). Differences in seed yield between the five lines as determined at 96 days after planting in 1955 were highly significant. Line 1-18 produced the lowest yield with 640 pounds of threshed seed per acre, line 12-3 produced 814 pounds per acre while lines 12-2, 12-8, and 12-21 yielded slightly more than 1,000 pounds of seed per acre. Since some shattering of early spikelets had already occurred before harvest and because many immature panicles were still present with only 58%-71% of the tillers yet headed at harvest time, the above yields do not accurately represent the total yield potentials of the five strains. Taking the habit of irregular maturation into consideration, the upper limit of yield of pure stands of wild oats might have been about 1,500 pounds per acre under the 1955 Edmonton plot conditions.

(c) Vegetative characteristics

Height measurements and observation over the three year period, as recorded in column six of Table IV, show that rank in height was very consistent among the five lines of wild oats. Plant height varied from extremely short to extremely tall. In ascending order of height the lines placed as follows: 12-21, 12-8, 12-2, 1-18, and 12-3. Figs. 2 and 3 illustrate variation in growth habit in the greenhouse and in the field respectively. Tillering capacity as discussed previously, modified other growth habits. Line 12-3,

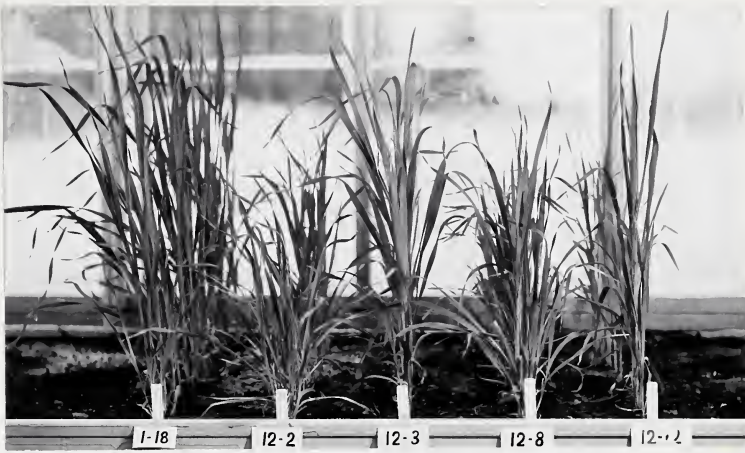


Fig. 2. Growth habit of wild oat lines in the greenhouse.



Fig. 3. Differences in growth habit of wild oat lines in the field. From left to right are lines, 12-2, 12-3, 12-21, 12-8, and 1-18. The three-row plots are separated by a buffer row of Thatcher wheat.

with a small number of tillers produced tall plants with very coarse, erect culms, while line 12-8 with more than twice the number of tillers produced short plants with semi-spreading, extremely fine, almost grass-like culms.

In 1953, lines 1-18, and 12-21 had appeared resistant to bacterial stripe/^{blight} of oats. All lines, however, were infected in 1954, and since the disease was not evident in 1955, no conclusions could be drawn regarding relative resistance of the lines to blight. Line 1-18 appeared to have the least blast of the five lines in all years but lines 12-2, 12-3, and 12-8 were extensively blasted, especially in 1953 when this disease was particularly severe.

The single plant progenies in the 1954 test appeared pure for all characters with the exception of the foliage color in two out of the three rows planted to line 12-2. In the progeny test of 1953, progeny of the original plant 12-2 had been of mixed foliage color, but all three single plants selected at harvest for 1954 planting had been glaucous-green in appearance. In 1954, only the progeny of one of these plants was pure for glaucous-green color while the progeny of the other two plants were either yellow-green or glaucous-green, with a predominant number of individuals with the latter coloration. This would indicate a segregation in line 12-2 for foliage color, with presence of the glaucous bloom dominant over the absence of bloom. Use of the bulked seed from the progeny of the one plant pure for glaucous color resulted in line 12-2 being pure for this character in the 1955 lines test. In all years,

lines 12-3 and 12-21 were pure for glaucous-green foliage color, while lines 1-18 and 12-8 were pure for yellowish-green foliage color. Etheridge (16, p. 122) found foliage color, as influenced by relative amounts of glaucous bloom, to be a constant character and made some use of it in his varietal classifications.

(d) Laboratory experiments

Germination tests

Germination tests were conducted at intervals after harvest of wild oat seed in 1955, in order to determine the length of time necessary for after-ripening of the seed of the five wild oat lines under dry storage conditions in the laboratory. Only mature, primary seeds were used in the tests and a quantity of such material was sorted out and set aside prior to beginning the series of tests. Random sampling was obtained by use of a vacuum seed counter which also facilitated placement of seeds on one half of a $6\frac{1}{2}$ x 11 inch sheet of number 1 filter paper. Duplicate, 50 seed samples were used for the folded paper towel method of germination, in a humid cabinet held at 20° C. An early count was made at 5-7 days and the remaining ungerminated seed left for 12 days to include late germinating seeds.

At four days after harvest, when the first test was made, the seed of the five lines gave 10%-48% germination with line 12-21 giving the lowest figure and line 12-2 the highest. The proportion of presumably sufficiently after-ripened seeds increased

rapidly. A test at 25 days after harvest showed the germination percentage of four lines to be 78%-86%, while at 50 days after harvest three lines gave 90%-95% germination. Line 12-8 appeared to possess the greatest degree of inherent dormancy, lagging far behind the others in the completion of after-ripening. This line gave 24, 54, 50, 78, and 90 percent germination at 4, 25, 50, 100, and 150 days after harvest, respectively. A germination test conducted in the spring (280 days after harvest) showed that dormancy had to a large degree also been overcome in the secondary seeds. Secondary seeds of three lines gave over 94% germination while line 12-8 gave 82%, and line 1-18 only 66% germination. From these results it might be inferred that these lines in general may not possess as high a degree of inherent dormancy as has been reported in the literature for other samples of wild oats. It must be kept in mind, however, that conditions of storage favored rapid disappearance of dormancy and also that degree of dormancy has been noted to vary from year to year (Bibbey, 7), presumably due to conditions prevailing during maturation.

Early seedling growth

Two observations made during the series of germination tests seem noteworthy. Shoot growth of lines 12-2 and 1-18, especially the latter, was extremely slow in the early tests, although root growth was not visibly different from that of the other three lines. The second observation concerned the number of seminal roots produced by the germinating seeds of the five lines.

Many of the seeds of line 12-2, and 12-21 produced an extra pair of lateral seminal roots, behaving in this regard like seeds of A. sativa. In many previous germination tests and in seedlings from the field, wild oats were never observed to produce more than three seminal roots. The production by wild oats of a lesser number of seminal roots than the cereal crops had been reported as being one of the factors responsible for comparatively slow growth of the weed in the early seedling stage (Pavlychenko and Harrington, 30). Germinating seeds of line 12-21 producing three, and seeds producing five seminal roots were transplanted in the greenhouse and grown to maturity. When the two lots of harvested seed were tested for germination, there were no differences in the number of seminal roots produced, and the majority of seeds produced four to five seminal roots.

In order to observe the relative rates of growth in the early seedling stage, a modification of the method of Kaiser and Albaum (23) was used. The apparatus was set up as illustrated in Fig. 4. A tube 11 cm. in circumference which snugly fitted the mouth of a half-pint milk bottle was constructed using graph paper ruled in 2 mm. divisions and backed by filter paper sheets. Dehulled seeds previously exposed to conditions favorable to germination for times long enough for penetration of the coleorhiza by the radicle were introduced peripherally, a centimeter apart, between the paper cylinder and the glass. The seedlings were then kept in the dark in a humid germinator cabinet held at 20° C., except when

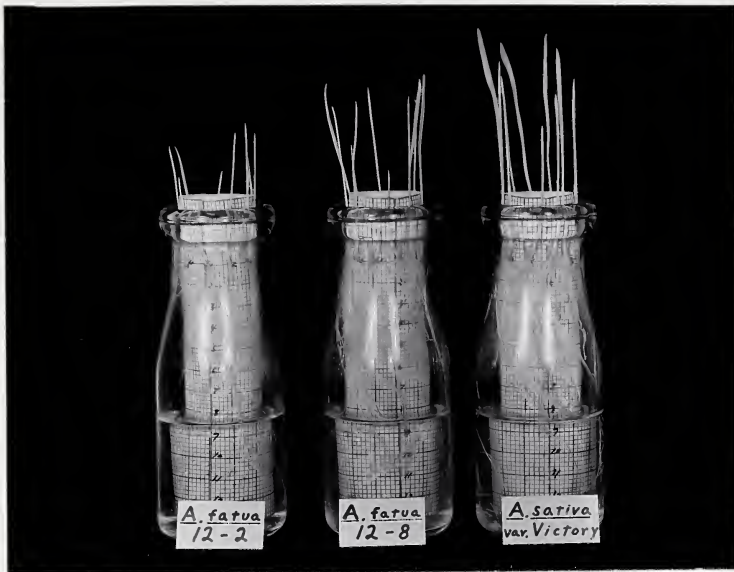


Fig. 4. Growth of A. sativa seedlings, and of a slow growing, and fast growing line of A. fatua after seven days.

measurements were being taken.

In most cases the primary seminal root grew straight downward in the air space below the seed position, thus permitting ready recording of root extension along the graph paper. Although the air in the bottles was humid, the graph paper prevented passage of enough free water to the seed for optimum germination and many seeds did not make further growth, or failed to grow normally and were discarded. The conditions of the test, however, did permit comparative data to be obtained and probably favored development of a larger than normal number of seminal roots. The test was conducted in duplicate, using both primary and secondary seeds of

the five wild oat lines and A. sativa var. Victory. In addition, immature, primary seeds of lines 1-18 and 12-21 were included in the test. The experiment was concluded after seven days, at which time most seedling shoots had ruptured the coleoptile and root proliferation of even the slowest growing samples had rendered root measurement extremely difficult.

Fig. 4 illustrates differences in growth rate between seedlings from primary seeds of slow, and fast growing A. fatua lines and between the much faster-growing A. sativa. The rate of elongation of the primary seminal roots and of the shoots of the various samples was plotted and found to be roughly linear with the growth curves of the slower-growing samples having less slope than those of the faster-growing samples. The approximate times in hours required for the primary seminal roots to attain a mean length of five cm. and for the shoots to attain a mean length of three cm. were obtained from the growth curves and are presented in Table V, as an index of the relative growth rates of the various samples. From Table V it is seen that wild oat lines 12-3, 12-8, and 12-21 were very similar in rate of growth and these lines displayed a much more rapid growth than lines 12-2, and 1-18. Strangely enough, growth rate of seedlings from secondary seeds proved more uniform than that of seedlings from primary seeds. Root growth of seedlings from secondary seeds of the three most vigorous A. fatua lines actually equalled that of seedlings from secondary seed of A. sativa.

Table V. Variation in early seedling growth from Avena seed samples. A. Time in hours for primary seminal roots to attain a mean length of 5 cm. and for shoots to attain a mean length of 3 cm.
B. Mean number and range in number of seminal roots produced in a humid atmosphere seven days after start of germination period.

Seed sample	A. Time in hours to attain:				B. \bar{M} and range in numbers of seminal roots produced:			
	5 cm. length		3 cm. length of shoot		Primary seed		Secondary seed	
	of primary seminal root							
	Primary seed	Secondary seed	Primary seed	Secondary seed	\bar{M}	Range	\bar{M}	Range
<u>A. fatua</u>								
1-18	168	118	168	180	3.4	3-5	3.3	3-5
12-2	138	118	150	138	5.1	4-6	4.8	3-6
12-3	98	100	124	154	4.4	3-5	3.6	3-5
12-8	98	98	122	138	4.6	3-5	3.2	3-5
12-21	110	100	124	124	5.2	4-6	4.4	3-5
1-18 immature	152	-	160	-	3.3	3-5	-	-
12-21 "	*	-	*	-	3.1	2-4	-	-
<u>A. sativa</u>								
var. Victory	82	98	102	120	6.1	4-8	4.8	4-8

* The growth rate of seedlings from immature, primary seed of line 12-21 fell off after five days and did not reach the 3 and 5 cm. level. It is doubtful if these seedlings would produce mature plants under field conditions.

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Although measurement of the primary seminal root gave an index of the rate of root elongation, it did not present the entire picture of the root resources of the young seedlings. Additional information was provided by a count of the number of seminal roots present at seven days. The mean number and the range in numbers of seminal roots for the various samples as given in Table V show striking variations. It will be seen that secondary seeds and immature primary seeds did not have the capacity to produce as large a number of seminal roots as mature, primary seeds and that A. fatua lines 12-2, and 12-21 produced the largest number of seminal roots as they had also done in the germination tests described previously. As many as six seminal roots were produced by A. fatua seed and up to eight for A. sativa under the conditions of this experiment.

From these results, it can be concluded that the similar or superior growth rates shown in some cases for seedlings from secondary seeds as compared with those from primary seed and also from immature seed as compared with mature seed of line 1-18, was due to less energy having been expended in production of extra seminal roots. In the case of line 12-2, the tendency to produce a greater than usual number of seminal roots may be a factor in its slower growth rate. The theory might be advanced that instead of the production of a lesser number of seminal roots (as compared to the cereal crops) being entirely a disadvantage to the wild oat seedling, this tendency might work to the favor of the weed by permitting more efficient direction of its smaller seed reserves.

At any rate, wild oats do not appear to be limited to production of a primary seminal root and one pair of lateral seminal roots but may under certain conditions produce a second pair of laterals as is normal for A. sativa (Hector, 19, p. 21).

Variation in the semi-permeability of the seed coat
with after-ripening and induction of secondary dormancy

The physiological basis for delayed germination, as previously discussed, has been shown by Atwood (4) and Johnson (20) to be due to a condition of the seed coat which limits the supply of oxygen to the embryo. As was suggested by Atwood, this limiting factor is probably related to the discovery by Brown (8) that the seed coats of cereals form a non-living semi-permeable membrane capable of excluding certain solutes while freely admitting water. As a check on Atwood's theory, a comparison of the rate of solute entry through the seed coats of after-ripened and non-after-ripened seeds was undertaken.

Two,3,5-triphenyltetrazoleum chloride, used as a chemical indicator of seed viability (32), was considered to be useful as a test solute since its passage in sufficient quantity through the seed coat is rapidly followed by staining of the embryo. The carmine-red color has been shown by Throneberry and Smith (40) to result from a reduction of the tetrazoleum salt as it acts as a hydrogen acceptor blocking respiratory activities of the seed.

The test procedure was standardized as follows, using the basic method of Eidmann as reviewed by Johnson (22) for sodium

biselenite, another chemical indicator of seed viability. Weighing bottles fitted with ground glass tops were used as containers in order to exclude atmospheric oxygen which has been shown (40) to interfere with the tetrazoleum reaction. The samples were checked at intervals of a few hours. Seeds stained a red color over the entire embryo were removed and their numbers recorded. The cumulative percentages of seeds stained after various periods of time were graphed for the various samples. After the curves had levelled off, the seed coats of the remaining seeds were removed over the embryo and the seeds returned to the solution. Details of the samples used in the test and the number of seeds used are given in Table VI, together with the results of germination tests run concurrently.

Table VI. Details of *Avena* seed samples used in semi-permeability studies, and their current germination.

Sample	Months from harvest	Number of seeds used in		% Germination	
		tetrazoleum tests		Primary	Secondary
		Primary	Secondary	Primary	Secondary
		seed	seed	seed	seed
<u>A. fatua</u>					
1-18	9 (field)	50	100	98	66**
12-2*	9 "	50	100	97	94
12-21	9 "	50	100	90	96
12-21	3 (Greenhouse)	--	50	--	2**
<u>A. sativa</u>					
var. Victory	9 (Field)	100	100	97	100

* Extra tests were made to determine the rapidity of embryo staining when the seed coat was not present to block entry of solute. One hundred seeds each of primary and secondary seed of line 12-2 were activated by presoaking, the seed coats removed over the embryo, and the seeds placed in solution.

** Ungerminated seeds remaining from germination tests could be expected to be in a state of induced secondary dormancy. These seeds were carefully dehulled and intact seeds tested for tetrazoleum uptake. Fifteen seeds from line 1-18 and 20 seeds from line 12-21 were transferred directly to the solution. Twenty additional seeds from line 12-21 were dried for 24 hours, then subjected to the standard test method.

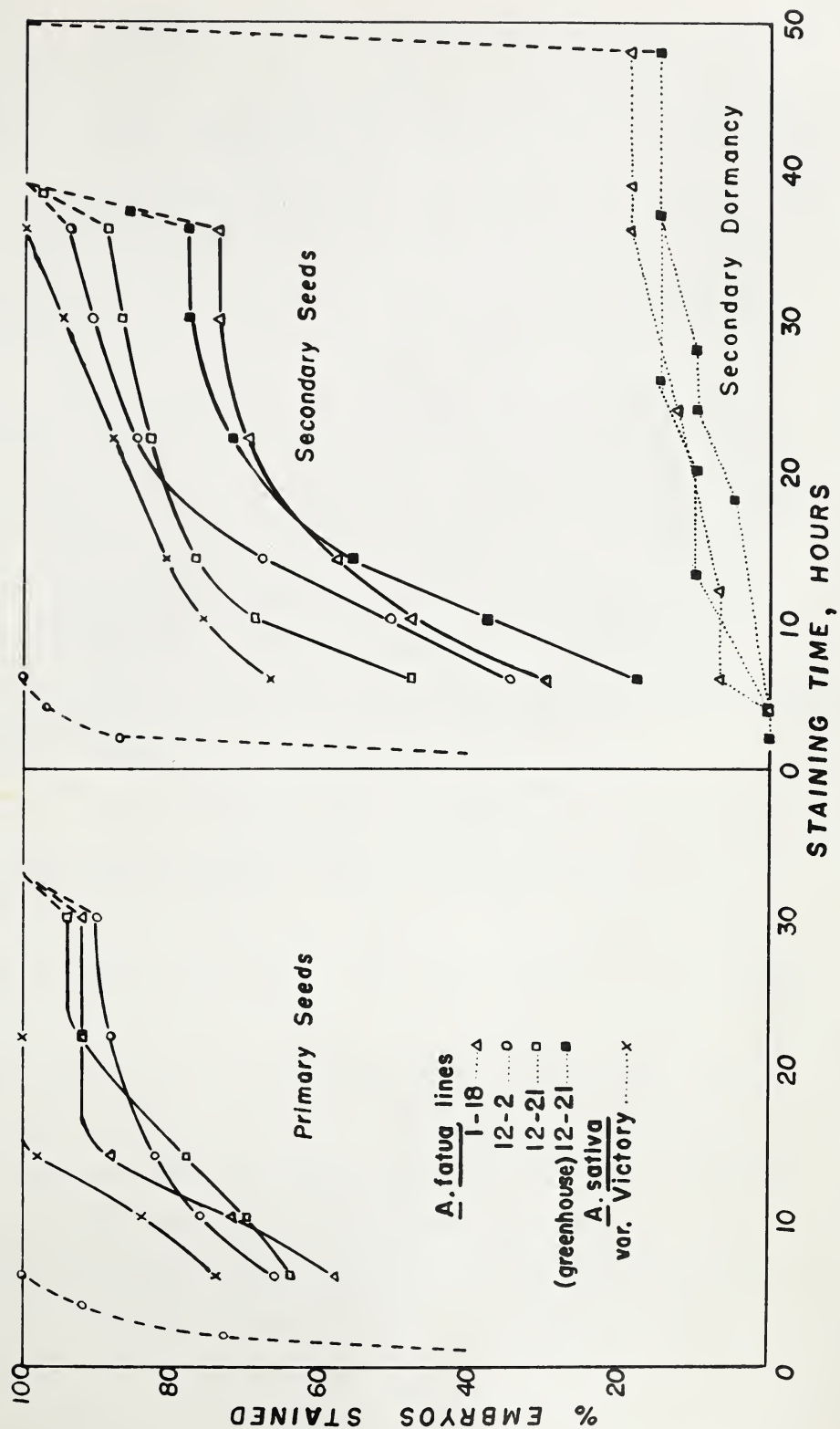


Fig. 5. Time - progress of tetrazolium chloride passage through Avena seed coats.

Experimental results are graphically illustrated in Fig. 5. Removal of the seed coat over the embryo before immersion in tetrazoleum solution, resulted in rapid staining of the embryos, as shown by the dash-line curves for primary and secondary seed of line 12-2. Embryos of these seeds were stained pink after only one hour of immersion and after two hours at least 75% were stained strongly. This indicated a very short time lapse between the passage of sufficient tetrazoleum salt through an intact seed coat, and embryo staining, validating the use of the staining reaction as evidence of nearly simultaneous passage of the solute through the seed coat. Added confidence in this assumption was provided by the fact that viable seed of all samples, (including those in which secondary dormancy had been induced) which showed no staining with time, stained rapidly when the seed coat over the embryo was removed with a sharp scalpel.

One of the most striking phenomena is the large proportion of seeds having apparently little resistance to the passage of tetrazoleum salt through the seed coat. This is illustrated by results showing that 18%-48% of even the secondary seeds of A. fatua stained in the first six hours. With the exception of wild oat line 12-21 from the greenhouse, which had only 2% germination, there is support for the postulation that these readily staining seeds are the ones most likely to germinate readily. The proportion of seeds fairly readily penetrated by tetrazoleum is indicated by those seeds with staining progressing up to about the fourteenth hour, when the curves for number of stained seeds rapidly dropped off,

the exact time depending upon the characteristics of the sample.

As shown in Fig. 5, the seed coats of primary seeds offered much less resistance to the passage of tetrazoleum than those of secondary seeds. This was found true for seeds of A. sativa as well as for seeds of A. fatua. Although the curves for passage of tetrazoleum into primary seeds of the three lines of A. fatua exhibited different initial slopes, the end results were the same, with 90%-94% of the seeds finally staining. The curves for secondary seeds divided these samples into two classes showing very different proportions of seed coats resisting the passage of solute. Readily germinable samples, A. sativa, and lines 12-2 and 12-21 of A. fatua gave a large proportion of stained seeds while the more dormant samples, line 1-18, and 12-21 (greenhouse) were less readily penetrated by tetrazoleum.

It might be expected that the curve for secondary seed of line 12-21 (greenhouse) which exhibited only 2% germination, would remain below that of secondary seeds of line 1-18, which germinated 66%. In reality the curve for line 12-21 rose slightly above that of line 1-18 although the difference in the final number of stained seeds was only 4%. From this comparison it would appear that although more seed coats of line 1-18 permitted early entry of tetrazoleum, the number of seed coats with high resistance to solute passage was similar for the two samples. It was not known how long the secondary seed of line 1-18 had possessed the moderate degree of after-ripening or what additional period would be required

for after-ripening of the three-month old seed of line 12-21. From these results it seems likely that only slight changes in the semi-permeability of the seed coat with time may be necessary for marked improvement in germinability. This is also indicated by the relatively small difference between the final parts of the curves for secondary seeds of A. sativa and A. fatua, line 12-2.

Ungerminated secondary seeds of line 1-18, and line 12-21 (greenhouse) remaining from germination tests were used in tetrazoleum tests as indicated in Table VI. From previous experience in germination tests and from the work of Johnson (20) it could be assumed that these seeds, placed under germinative conditions before after-ripening was complete, would be in a state of induced secondary dormancy. The results of the tetrazoleum tests on seeds presumed to be in a condition of secondary dormancy are shown by the dotted-line curves of Fig. 5. Since only 15 seeds of line 1-18, and two 20 seed samples of line 12-21 were tested, the staining of only one seed would result in a magnified value of 5%-7%. Thus the results from these three samples are best combined to assess the influence of induced secondary dormancy on seed coat semi-permeability. It is seen that the seed coat of very few seeds permitted passage of tetrazoleum but embryos stained readily when the enveloping seed coats were removed at 48 hours. The placing of incompletely after-ripened seeds under germinative conditions thus appears to result in a resumption of a high degree of semi-permeability of the seed coat.

From the combined results obtained with the various samples of Avena exhibiting various degrees of germinability, it can be concluded that the degree of permeability of the seed coat changes with time. This process undoubtedly intimately influences the threshold oxygen supply, preventing or permitting germination.

These conclusions, using the above methods, are drawn from results best considered as preliminary in nature. Ideally the experiment should be repeated, using samples of genetically uniform, freshly harvested seed, tested at intervals over the period required for complete after-ripening of both primary and secondary seeds, using a standardized procedure throughout, to follow the changes in seed coat permeability with after-ripening. Much additional information could be obtained by use of several chemical indicators of viability such as certain tellurium salts and sodium biselenite (22).

SUMMARY - GENERAL DESCRIPTIONS OF THE PURE LINES

Within three years of tests in which the five lines had been grown as individual plant progeny plots for two years, and as bulked seed the third year, the lines became stabilized in all observed characters as pure lines. These lines originated from the progeny test outlined in Section B, and they represented the extreme variations observed. Thus the following description of the lines will serve as a summary of the variations recorded in Section B as well as of the results of Section C. The five lines

fall into three varieties of A. fatua L. spp. fatua (L.) Thell. on the basis of varietal separation by seed type. Differences in the three lines classified as variety pilosissima would thus place these lines as distinct strains of that variety. It might be expected that strains of all varieties exhibiting these variations in vegetative growth habit, would be found under natural conditions.

Variety vilis (Wallr.) Hausskn.

Line 1-18: Seeds dark grey, lemma completely glabrous, callus hairs short, early seedling growth slow, foliage yellow-green, plants tall, culms erect, coarse, tiller production low, early heading, fairly even maturity.

Variety intermedia (Leslib.) Lej. and Court.

Line 12-3: Seeds dark brown to black, lemma pubescent, callus hairs short, foliage glaucous-green, plants very tall, culms erect and very coarse, tiller production low, late heading, fairly even maturity, susceptible to blast.

Variety pilosissima S.F. Gray

Line 12-2: Seeds dark brown to black, lemma strongly pubescent, callus hairs long, early seedling growth slow, tendency for production of a greater than normal number of seminal roots, foliage glaucous-green, plants medium height, culms semi-spreading and moderately fine, tiller production moderate, early heading, very uneven maturity, very susceptible to blast.

Line 12-8: Seeds dark brown to black, lemma strongly pubescent, callus hairs long, foliage yellow-green, plants short, culms spreading

and extremely fine, tiller production extremely high, intermediate to early heading, extremely uneven maturity, very susceptible to blast.

Line 12-21: Seeds dark brown to black, lemma glabrous, callus hairs long, tendency for production of a greater than normal number of seminal roots, foliage deep glaucous-green, plants very short, culms erect and moderately coarse, tiller production moderate, early heading, fairly even maturity. This strain is not true to varietal type, having glabrous rather than pubescent lemma but is placed under var. pilossissima rather than under var. glabrata Peterm., which has yellow to dark grey seeds and forms only a small proportion of the wild oat population of the Prairie Provinces (Lindsay, 26).

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PART II. CHEMICAL CONTROL OF THE WILD OAT

INTRODUCTION AND REVIEW OF THE LITERATURE

The nature and extent of the problem, and the economic significance of the wild oat as a weed have been reviewed in part I. It will suffice here to reiterate that under the present system of grain - fallow rotation practiced over most of the Northern Great Plains region, the wild oat has not been successfully kept in check by tillage methods alone. Spectacular progress in chemical weed control has led to the hope that such supplementary techniques may facilitate control of this serious weed.

In 1937, before the advent of the modern organic herbicides, Cook (11, 12), screened 76 chemicals, most of them inorganic compounds, for their effect on wild oats, wild mustard (Brassica kaber (D.C.) L.C. Wheeler), stinkweed (Thlaspi arvense L.), and lamb's quarters (Chenopodium album L.). Only a few of these chemicals, at dosages of between 800 and 2000 pounds per acre, gave satisfactory control of wild oats. The relative resistance to most substances as measured by the "certainly lethal dose", was 1:1:2:7 for wild mustard, stinkweed, lamb's quarters, and wild oats, respectively. The early history of chemical weed control, as reviewed by Robbins, Crafts, and Raynor (32), and by Ahlgren, Klingman, and Wolf (1), makes no mention of wild oat control with the older herbicides.

During the past few years a number of approaches to chemical control of wild oats have been developed during evaluation of a continually increasing number of modern herbicides, mainly systemic in action. These methods may be classified and defined as follows:

1. Pre-planting: Short term soil sterilants are applied to the soil in the fall or spring prior to crop planting. Some crops may be relatively resistant to the wild oat control chemical, but when crops planted are susceptible to the herbicide, enough time must be allowed for residual effects to disappear. Chemical summerfallow with herbicides applied to the soil may be considered a form of pre-planting treatment. Under dry conditions or with chemicals of low water-solubility, incorporation by means of tillage is needed to place the herbicide in moist soil and in a favorable position relative to the wild oat seeds.
2. Residual pre-emergence: Short term soil-sterilants are applied after sowing but before emergence of resistant crops or weeds. With this approach incorporation of the chemical into the soil is not possible, with the exception of that obtainable with shallow post-seeding tillage.
3. Residual post-emergence: This method concerns the use of herbicides which have very little effect on well established crop seedlings yet are toxic to germinating wild oat seeds and non-emerged seedlings. Very often cereals sown early in the spring (or even after the first wild oat growth has been destroyed)

emerge in temporarily weed-free rows only to be overcome by late-emerging wild oats. Residual post-emergence control involves sowing the crops as early as possible, and promoting vigorous growth by fertilizing, packing, etc., with the aim of providing chemical control of germinating wild oats and other weeds. Even if wild oats are not completely eradicated but merely stunted, the crop is given an opportunity to compete more effectively.

4. Contact pre-emergence: This technique can complement the delayed seeding method of cultural control. Wild oat growth in the spring is first encouraged and the crop drilled directly into the stand. Timing of sowing and spraying requires that the wild oats be at the optimum stage for destruction by "contact" herbicides or growth suppressants applied to their foliage just before crop emergence. Contact herbicides injure the tissues which are contacted by the treatment. There is no appreciable translocation of such chemicals. This approach is designed to permit crops to be sown somewhat earlier. Moreover, a second growth of wild oats would not be encouraged since the soil would be disturbed less than is the case during destruction of the wild oat growth by tillage. The herbicides used must have little residual effect in the soil, yet assure a complete kill of wild oats since escapes would have the advantage of being already established prior to crop emergence. The risk of adverse weather interfering with timely chemical application is a serious disadvantage of this control method.

5. Induction of seed sterility: Maleic hydrazide is applied to wild oats in the "milk stage" to arrest embryo development. Treatment is selective if the crop (e.g. barley), flowers early enough ahead of the wild oats to escape induction of sterility by the herbicide (10, 22). Any cultural practice such as fertilization, and post-seeding tillage, which encourages earlier crop maturity or delayed wild oat growth broadens the margin of selectivity.

6. Breakage of dormancy of wild oat seed in the soil: Reference has already been made to the agronomic problems attributable to the irregular germination of wild oats. Johnson (20) found dormancy of wild oat seeds could be almost completely overcome in the laboratory by soaking of seed in a 2% potassium nitrate solution for 12 - 24 hours. Recently McCurdy (26), and Wilson and Friesen (42), have obtained stimulation of wild oat germination in the soil following heavy applications of nitrogenous compounds such as potassium nitrate, calcium cyanamide, and anhydrous ammonia.

The results of most of the recent experiments on chemical control of wild oats have been abstracted in the North Central Weed Control Conference research reports, and the Western Section of the National Weed Committee (Canada) research reports. The results reported in these abstracts have been summarized under a specific wild oat project in the latter since 1952 (16, 23, 24), and in the annual weeds section of the former (15). In addition, a few full length papers have been published (4, 5, 22, 39, 40).

Table VII provides a summary based upon the abstracts in the 1952-1956 research reports (138 abstracts). It lists the chemicals that have been tried against the wild oat, the range of rates used, and comparisons of effectiveness under various methods of application determined as the ratios of successes to failures. The limitations of these ratios becomes obvious when one attempts to assess the results of a test from the limited information contained in an abstract. For the present purposes, and considering the resistant nature of the wild oat plant, the killing of 75% or more of the weed population was considered a "success". In many cases actual data were not present and it was necessary to base the assessment of the worth of a treatment upon the author's expressions of opinions in the abstract. The reliability of any given ratio probably also depends upon the number of trials, as indicated in parentheses in the table. In most cases a small number of trials is indicative either that the chemical showed little promise against the wild oat or was not adapted to a given type of application.

Throughout the present paper the various herbicides will be referred to by the use of the abbreviations given in Table VII. The recurring term, pound or pounds per acre, will be abbreviated to lb./A., similarly oz./A., and gal./A. (Imperial gallons). The accepted practice of expressing dosages as weight of active ingredient is followed throughout, except in the case of chemicals applied in bulk, such as calcium cyanamid, or in large volume, such as aromatic oil, and Crag. Herbicide No. 3. Further reference to

TABLE VII

Summary of herbicidal treatments on wild oats reported in abstract form in the North Central Weed Control Conference research reports (1952-1956), and the Western Section of the National Weed Committee (Canada) research reports, (1953-1956)

Chemical name and abbreviation	Range of Rates Used lbs/Acre	Ratio of Successes: Failures (number of trials in brackets)			
		Pre-emergence		Post-emergence	
		Incorporated Fall	Not incorporated Spring	Incorporated Fall	Not incorporated Spring
bis-(dichloro)phenoxyethyl oxalate (Sesin)	5-100	0 (1)	0 (1)	0 (1)	0 (2)
2,4-dichlorophenoxyethyl Sulphate (Herb. No. 1)	5-20	-	-	-	0 (1)
2,4,5-trichlorophenoxyethyl Sulphate (Natrín)	5-10	-	-	-	0 (2)
N-1 naphthylphthalamic acid (NPA, alanap)	2-40	-	-	0 (1)	0 (3)
2,4-dichlorophenoxyacetic acid (2,4-D)	1-50	.50 (9)	1.0 (2)	.33 (4)	1.0 (2)
3,4-dichlorophenoxyacetic acid (3,4-D)	4-10	2.0 (3)	1.0 (1)	1.0 (1)	0 (1)
2-methyl-4-chlorophenoxyacetic acid (MCPA)	10-25	3.0 (4)	-	0 (1)	-
sodium trichloroacrylate (EH 3890)	2-15	-	-	-	0 (1)
α -cyano- (2,4-dichlorophenyl) acrylic acid	2.5-10	-	-	-	-
borate-2,4-D mixtures (FB sprays)	25-34 (2,4-D)	0 (1)	-	0 (1)	-
chlorobenzoic acids (2,5,6-TBA, 2,3,5,6-TBA, etc)	1-6	0 (2)	0 (2)	0 (2)	0 (3)
hexachloroacetone (Cmd. 1106)	2-8	-	-	-	-
trichloroacetanilide (Cmd. 2025)	2-8	-	-	-	-
trichloroacetylurea (Cmd. 2015)	2-8	-	-	-	-
dichloral urea (DCU)	2-40	0 (1)	0 (1)	0 (1)	0 (5)
phenyldimethylurea (PDU, Urab)	1.5-3	-	-	-	0 (1)
3-P-chlorophenyl-1-1-dimethylurea (DMU, Monuron)	$\frac{1}{2}$ -100	1.0 (4)	.33 (4)	0 (2)	.57 (11)
1-n-butyl-3-(3,4-dichlorophenyl)-1-methylurea (neburon)	2-4	-	-	-	0 (1)
Trichloroacetic acid (TGA)	2-30	1.67 (8)	.75 (10)	2.0 (6)	0.20 (18)
2,2-dichloropropionic acid (dalapon)	1-20	0 (3)	.50 (3)	1.0 (2)	2.5 (7)
2,2,3-trichloropropionic acid (2,2,3-TPA)	2-40	-	0 (2)	-	0 (2)
Xanthogen disulphide	5-30	-	-	-	0 (1)
potassium cyanate	10-20	-	-	-	0 (1)
calcium cyanamide	88-400	-	0 (1)	0 (2)	-
isopropyl-N-phenylcarbamate (IPC)	1-48	3.00 (24)	2.40 (27)	1.5 (10)	.44 (13)
isopropyl-N-(3-methylphenyl) carbamate (5518)	2-8	0 (2)	.67 (5)	0 (1)	0 (1)
isopropyl-N (3-chlorophenyl) carbamate (CIPC)	1-48	3.00 (16)	2.50 (14)	.20 (6)	1.67 (8)
butyl-N-(3-Methylphenyl) carbamate (5519)	2-8	0 (1)	0 (2)	0 (1)	-
sec-butyl-N-(3-chlorophenyl) carbamate (BCPC)	4-8	-	0 (2)	-	-
(1-chlorophenyl-2)-N-(3-chlorophenyl)carbamate (CPGPC)	4-8	-	0 (1)	-	-
2-chloroethyl-N-(3-chlorophenyl)carbamate (T-595)	4-5	-	0 (1)	-	0 (1)
trichlorobenzyl diisopropylidithiocarbamate (553-T)	1-10	0 (1)	0 (2)	0 (1)	0 (4)
2,3-dichloroallyldiisopropylidithiocarbamate (552 I)	1-10	1.0 (1)	0 (1)	0 (1)	0 (3)
2,3-dichloroallyldiethylidithiocarbamate (551 E)	1-10	0 (1)	0 (2)	0 (1)	0 (4)
2-chloroallyl diethylidithiocarbamate (CDEC)	1-10	0 (3)	.33 (12)	0 (1)	.17 (7)
α -chloro-N-N-diallylacetamide (CDAA, Rendox)	1-12	.20 (6)	1.71 (12)	0 (2)	1.28 (16)
α -chloro-N-N-diethylacetamide (CDEA)	1-10	0 (2)	.75 (7)	0 (1)	.40 (7)
Dow Chemical Co. coded (M-757)	10-20	-	0 (1)	-	-
Dow Chemical Co. coded (M-775)	10-40	-	1.0 (1)	-	-
Rhoem & Haas Chemical Co. coded (FW-450)	5-20	-	0 (1)	-	0 (1)
Compound 9802	4-6	-	-	-	1.0 (1)
3-amino-1,2,4-triazole (At, Amizol)	1-20	0 (1)	0 (2)	0 (2)	0 (2)
3,6-endohexahydrophthalic acid (endothal)	$\frac{1}{2}$ -40	1.0 (4)	.33 (4)	0 (2)	.20 (6)
pentachlorophenyl (PCP)	2.5-10	-	-	-	-
dinitro-o-sec-butylphenol (DNBP)	2.5-10	-	-	-	0 (1)
aromatic petroleum oils (Stoddard solvent)	10-40 (gal/A)	-	-	-	-
aromatic coal tar derivative (Crag. Herb. # 3)	5-40 (gal/A)	-	-	-	-
1,2-dihydropyridazine-3-S dione (maleic hydrazide MH)	2-20	0 (2)	-	0 (1)	0 (1)
$\frac{1}{4}$ -2 (as seed sterilant- Applied to Panicles at milk stage)					2.0 (9)
					12.0 (13)

the literature will be made in the body of this paper when they aid in the interpretation of results, and in the discussion.

The writer's experiments on chemical control of wild oats, recorded here, were conducted at the University of Alberta in the period from 1952-1956. Although attention was also given to the effects of chemicals on crops in which the wild oat is commonly a problem, the major emphasis was directed to responses of the weed itself. It was considered desirable that initially, the effect of the chemicals on the wild oat be measured independently, and without the complications of crop competition. Two broad types of herbicidal application were used, (1) application to infested soil before wild oat emergence, and (2) application to wild oat foliage.

MATERIALS AND METHODS

In the majority of tests, wild oats were sown into the experimental areas because suitable natural infestations were not available. Sown plots permitted use of well after-ripened seed, giving a uniform stand which permitted reliable comparisons between treatments, and the use of standard field plot techniques. In the 1953 and 1954 seasons, rod length plots were used, and in 1955, half-rod length plots. Plots were of sufficient width to allow use of a self-propelled, 4-row plot seeder, and to prevent lateral movement of herbicide from adjacent plots into yield rows. Data for green weight, or plants counts were obtained from the center two rows of each plot at maturity. The experimental design

consisted of randomized blocks where treatment numbers were small, or split plot designs where larger numbers of treatments indicated use of "rates" as whole plots, and "chemicals" as split plots. Four replications were used in most experiments. Exceptions to the above methods are indicated in the text. Statistical analysis, in most cases, was made on the original data as they were obtained from the field. While the original data were suited for assessment of the individual experiment, they did not permit direct comparison of results between experiments or years. To facilitate such comparisons, many of the treatment means were expressed as a percentage of the check means (check = 100%). New "least significant difference" values, with the essential proportions unchanged, were also calculated as a percentage of the check.

The chemicals for each plot were measured out separately into milk bottles, mixed with an amount of water equivalent to 50 gal./A. and applied on an area basis using a modification of the small plot sprayer described by Ries and Terry (32). This sprayer consisted of a clamp head enabling chemicals to be sprayed directly from the bottles, and was powered by a portable, gasoline driven air compressor operated at 25 p.s.i. With tests involving large areas, a knapsack sprayer or field sprayer was used. For greenhouse and laboratory tests involving application on a "pounds per acre" basis, the material to be sprayed was placed in the center of a square yard area, and the calculated amount of chemical applied with the small plot sprayer, using the equivalent of 100 gallons of water per acre to ensure even distribution.

Many germination tests were made during the course of investigations concerning effects of chemicals on seed. Dormancy was to a large extent overcome by dry storage in the laboratory for several months, thus allowing uncomplicated assessment of the effect of chemicals on germination. Where possible the "folded paper towel" method was used, with the seed selected at random from a given sample by means of a vacuum-type seed counter placing 50 seeds on one half of a $6\frac{1}{2}$ x 11 inch sheet of Whatman No. 1 filter paper. Nine folded sheets were arranged on several layers of absorbent paper in a $15\frac{1}{2}$ x $15\frac{1}{2}$ inch tray, and the tray held in a humid, controlled temperature cabinet at 20° C. for the duration of the test.

For detailed studies the seeds in a germination test were classified, after at least 12 days of test, as follows:

I. Germination with good growth: Normal germination from which emergence under field conditions could be expected. Good root elongation (at least 1 seminal root), and plumule extended at least half the distance of the coleoptile (36).

II. Germination with only slight growth: Abnormal seedlings which probably would not emerge under field conditions, weak seedlings with radicle or shoot just visible, or with only sufficient growth to spread the lemma and palea of the hull without actual emergence of seedling parts.

III. No visible sprouting: Seeds dormant or dead. With oats, after removal of hull, seeds could be placed into one of three subclasses:

- A. Caryopsis sound and of normal color, little evidence of contamination, and seed apparently truly dormant.
- B. Slight growth of embryo, as in class II, but growth ceased before hull lifted, thus seed was still viable but germination weak or chemically inhibited.
- C. Seed dead, allowing action of microorganisms; darkened seed coat and germ end indicated recent attack, probably during germination test, while a completely decomposed caryopsis indicated seed probably dead for some time.

RESULTS FROM APPLICATION OF HERBICIDES TO THE SOIL

Use of TCA as a short term soil sterilant

The first of the present series of experiments with herbicides for wild oat control at the University of Alberta, was begun May 16, 1952 (13). Granular cyanamide was spread dry at the rate of 200, 300, and 400 lbs. of bulk chemical per acre; CMU at 1, 5, and 10 lbs./A.; and TCA at 10, 25, and 50 lbs./A., were sprayed on the soil surface, and all chemicals immediately disked into the soil. Only the TCA had any measurable effect, reducing the green weight of wild oats to 80, 51, and 24% of the untreated check plots at the 10, 25, and 50 lb. rates, respectively.

On September 21, 1952, TCA was applied at 5, 10, 20, 40, and 80 lbs./A. Four rows of wild oats had been sown two days previously, and plots were of sufficient width to permit spring planting in 1953, of wheat (May 7), wild oats (June 15), and

flax (June 26). The dosage response curves for the wild oats and wheat are shown in Fig. 6. Emergence of wild oat plants from seed in contact with the chemical over the winter was markedly reduced, compared with the number of seedlings appearing in the fall. This may have been due to some toxic effect of TCA on ungerminated seeds but can more likely be attributed to the leaching of TCA to the soil level occupied by the seedling roots and subsequent destruction of seedlings after germination. For the fall planted wild oats germinating in the spring "panicle-count" data were closely correlated to green weight reduction with treatment. The effect of TCA was primarily a reduction in the emergence of plants, and secondly, stunting of the escapes. Heading was almost totally suppressed by the 40 lb. rate. Fig. 7a illustrates the deformation due to the shortening of the plant and panicle internodes, which occurred at even the 10 and 20 lb. rates. The late spring planted wild oats showed a fairly high tolerance to TCA with only a 41% reduction in green weight at the 80 lb. rate. That considerable TCA was still present was indicated by very serious damage to late planted flax by the 40 and 80 lb. treatments. Significant reduction in germination and green weight of early spring wheat from only 5 lbs./A. of TCA indicate the extreme sensitivity of this crop to this chemical. No adverse effect could be noted on fall rye planted in September, 1953, one year after chemical application.

An unreplicated field scale test was begun in the autumn of 1952. A large disked area was sown to wild oats on October 9, and a strip treated on October 10, with TCA at 40 lbs./A. On

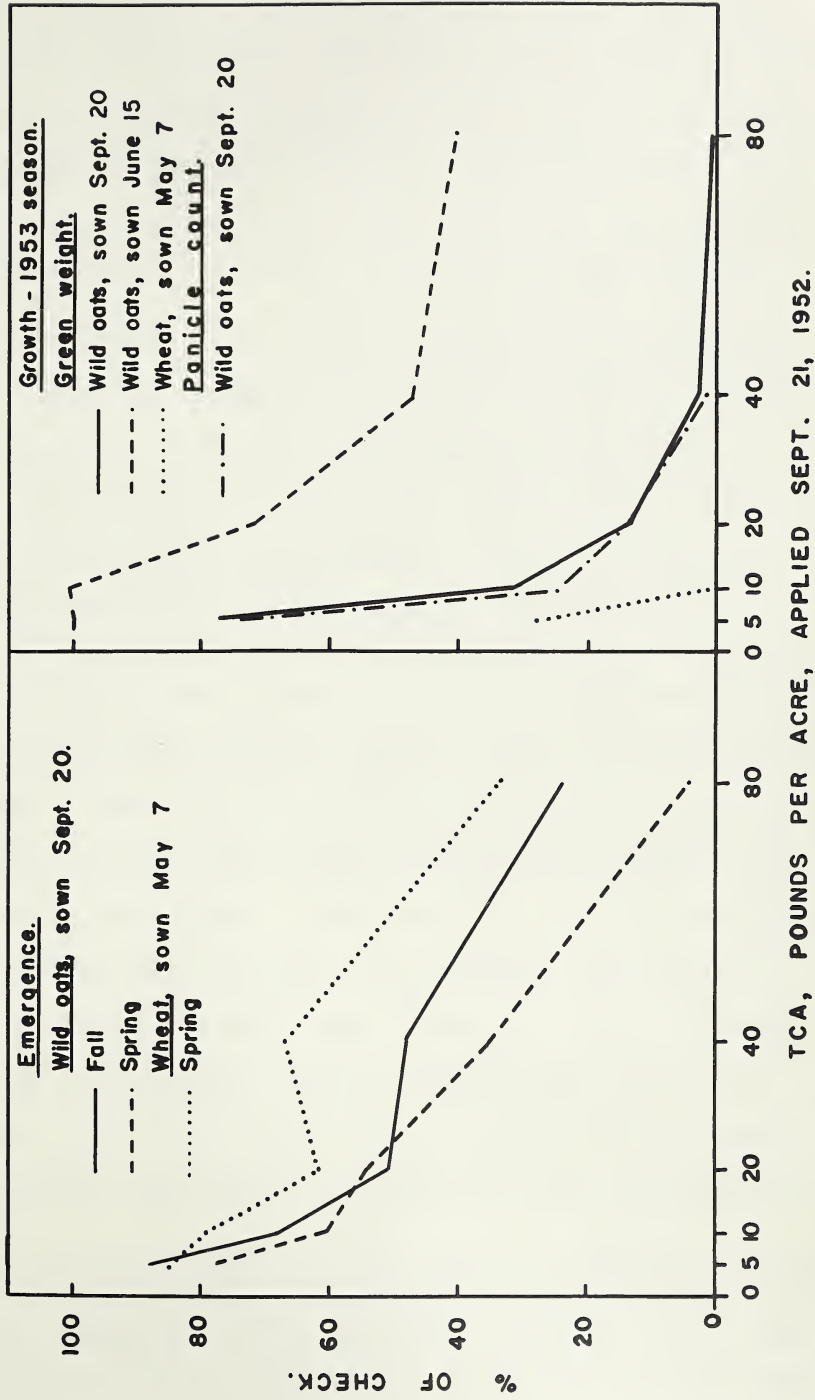


Fig. 6. Dosage response curves for TCA on wild oats and wheat.

May 11, 1953, a 50 lbs./A. application was made. Crops were sown at right angles to part of the treated area. Wheat, oats, barley, and fall rye were sown May 7, and flax, June 8. No wild oat growth occurred in the fall but germination in the spring was so complete that adequate seed samples could not be obtained from the soil to determine treatment effect on ungerminated seeds. Fall treatment reduced the stand of wild oats to 28% of that on the untreated area, as contrasted to a reduction of only 55% of the check from spring application. Flax was the most resistant crop followed by oats, rye, barley, and wheat. Cultivated oats and wild oats showed a very similar response to TCA. In this test as in the previous one, no effect could be noted on fall rye planted in September, 1953, even from the 50 lbs./A. spring application.

The wild oats on part of the untreated area from the above field scale test were allowed to shatter seeds on the soil surface, the straw was removed, and the area thoroughly disked to mix the seeds with the soil. This resulted in conditions similar to those of a natural infestation. A three-replicate split-plot experiment was laid down, using four whole plot treatments consisting of chemicals sprayed October 1, 1953, and May 17, 1954, undisturbed or incorporated by disking one day after spraying. Split plot treatments consisted of check, Sesin at 25, 50, and 100 lbs./A., CIPC at 5, 10, and 20 lbs./A., and TCA at 10, 20, and 40 lbs./A.

No emergence of wild oats occurred in the fall but spring emergence, beginning two days after spring treatment, was so rank as to make plant counts impractical. Visual observations indicated

severe damage from TCA at 20 and 40 lbs./A. but with the effect reduced by disking. Fall application was again superior to spring application of TCA. Extent of killing from the high rates of CIPC, applied in the fall and incorporated with the soil, surpassed that of fall applied TCA, while other CIPC treatments gave poor results. Sesin showed little effect against wild oats except at the 100 lb. rate, fall-applied and undisked, but gave good control of broadleaved weeds germinating early in the spring. Later in the season, escapes from all chemical treatments tended to fill out the stand and much second growth occurred from severely stunted plants, resulting in no significant differences in green weight at heading time. CIPC-treated-plants exhibited a much weakened root system and were badly lodged following heavy rainstorms.

Table VIII summarizes the results obtained with TCA over a four year period.

Table VIII. Effect of TCA on green weight of spring-emerged wild oats, data expressed as percentage of check (Check = 100%)

Expt. No.	Date Applied	Rainfall*	Rate lbs./A					L.S.D. @5%	Remarks
			10	12.5	25	40	50		
1	May 16, '52	0.5	80		51		24	8.4	Incorporated
2	Sept. 22, '52	-	32			3		51.5	see fig. 1
3	Oct. 9, '52 May 11, '53	- 0.08				28	55	-	fall-applied superior
4	May 14, '53	0.08		89	94		41	-	dry season
8	Oct. 1, '53 May 17, '54	- 1.71	Natural infestation; applied at 10, 20, 40 lbs./A; visual observation indicated fall-applied superior, incorporation not advantageous.						
9	June 2, '54	2.64		89	48		40	16.4	wet season
12	May 12, '55	0.38			70		47	13.6	dry season

* Rainfall in inches in the two week period following application, the period in which germinating wild oat seeds, and emerging seedlings would be expected to be most susceptible to herbicides in the soil.

In addition to the tests described above, TCA was applied May 14, 1953, June 2, 1954, and May 12, 1955, as part of larger scale experiments which included several other soil treatments. A comparison of the effectiveness of TCA with these other chemicals will be made later. In each of these tests, wild oats had been planted one or two days previously and chemicals were not incorporated with the soil. In spite of great differences in rainfall in the various two week periods following spraying (the interval in which the germinating seeds and young emerged seedlings should be most susceptible), there was only a 7% difference in control between these three experiments at the 50 lbs./A. rate. On the other hand, control from the 25 lbs./A. rate was vastly superior in the wet spring of 1954, to that secured in the drier springs of 1953, and 1955. In general, however, the data of Table VIII would indicate that results with TCA, a readily soluble herbicide, were not markedly influenced by moisture supply.

Other soil-treatments with herbicides

Throughout the seasons of 1953, 1954, and 1955, a large number of herbicides were tested which act primarily to prevent seed germination or to suppress growth of young seedlings when taken up from the soil by the roots. Table IX shows the effect of eight of these soil sterilants applied May 14, 1953, two days after planting wild oats. A split plot design was used with low, intermediate, and high rates apportioned to whole plots, and chemicals to split plots. All chemicals were applied at 5, 10, and 20 lbs./A. with the exception of TCA which was applied at 12.5, 25, and 50 lbs./A.

Table IX. (Expt. 4) Effects of herbicides sprayed on the soil May 14, 1953, on wild oats planted two days previously.

Herbicide **	Rate lbs./A.	Green weight (% of check, \bar{M} of 4 replicates)			
		Rate I	Rate II	Rate III	Herb. Mean
CIPC	5, 10, 20	79	50*	18*	49.9*
CIPC(disked)	5, 10, 20	65	61	27*	51.4*
IPC	5, 10, 20	95	55	16*	56.7*
IPC(disked)	5, 10, 20	90	66	38*	65.4*
CMU	5, 10, 20	106	73	20*	67.4*
TCA	12.5, 25, 50	89	94	41*	75.0
Sesin	5, 10, 20	99	104	96	99.8
DCU	5, 10, 20	105	97	100	100.8
Herb. #1	5, 10, 20	110	112	96	106.0
Alanap	5, 10, 20	105	109	109	107.6
Check		100%	100%	100%	100%
L.S.D. @ 5% level		46.2	50.1	50.7	28.7

** See Table VII for complete names of chemicals.

* Indicates a significant reduction at the 5% level.

With the exception of CIPC at 10 lbs./A., no significant reduction in green weight of wild oats resulted from the low or intermediate rate of any chemical. The chemicals are listed in Table IX in ^{numerical} order of effectiveness. CIPC was consistently more efficient than IPC, while CMU and TCA gave still less reduction in green weight of wild oats. It is of interest that residual effect from CMU was apparent in cereal crops sown two years later, after

the area had been summerfallowed. Since CMU acts as a long term soil sterilant at the high rates necessary for wild oat control, it was dropped from further testing. Disking did not significantly reduce the efficiency of IPC and CIPC, but a trend towards less effect following incorporation in this experiment was indicated for both chemicals, especially with IPC. It was hoped that shallow disking might make herbicidal activity less dependent on precipitation by placing the chemical in moister soil where it would be more readily contacted by the wild oat roots. The disking, however, apparently dispersed the chemical so it was present in less effective concentration. The rather poor herbicidal response in this experiment may be attributed to a long period of dry weather following application, while adequate soil moisture was present at seed depth for rapid wild oat growth. Thus the plants were well established before much chemical came into contact with the roots. CIPC and IPC did inhibit germination to some extent but the effect of most herbicides was manifest only after rainfall occurred 15 - 19 days following spraying.

DCU, Herb. #1, Sesin, Natrin, and Alanap had no effect on the green weight of wild oats. Some stunting and formative effects on a few wild oat seedlings was noted with the 20 lb. rate of DCU (Fig. 7b) but the effect was only temporary. This group of chemicals was of special interest since they may be considered as selective soil sterilants or seedling toxicants in that they do not appear to harm an established crop, yet inhibit germination and growth of non-emerged seedlings (21, 37). These

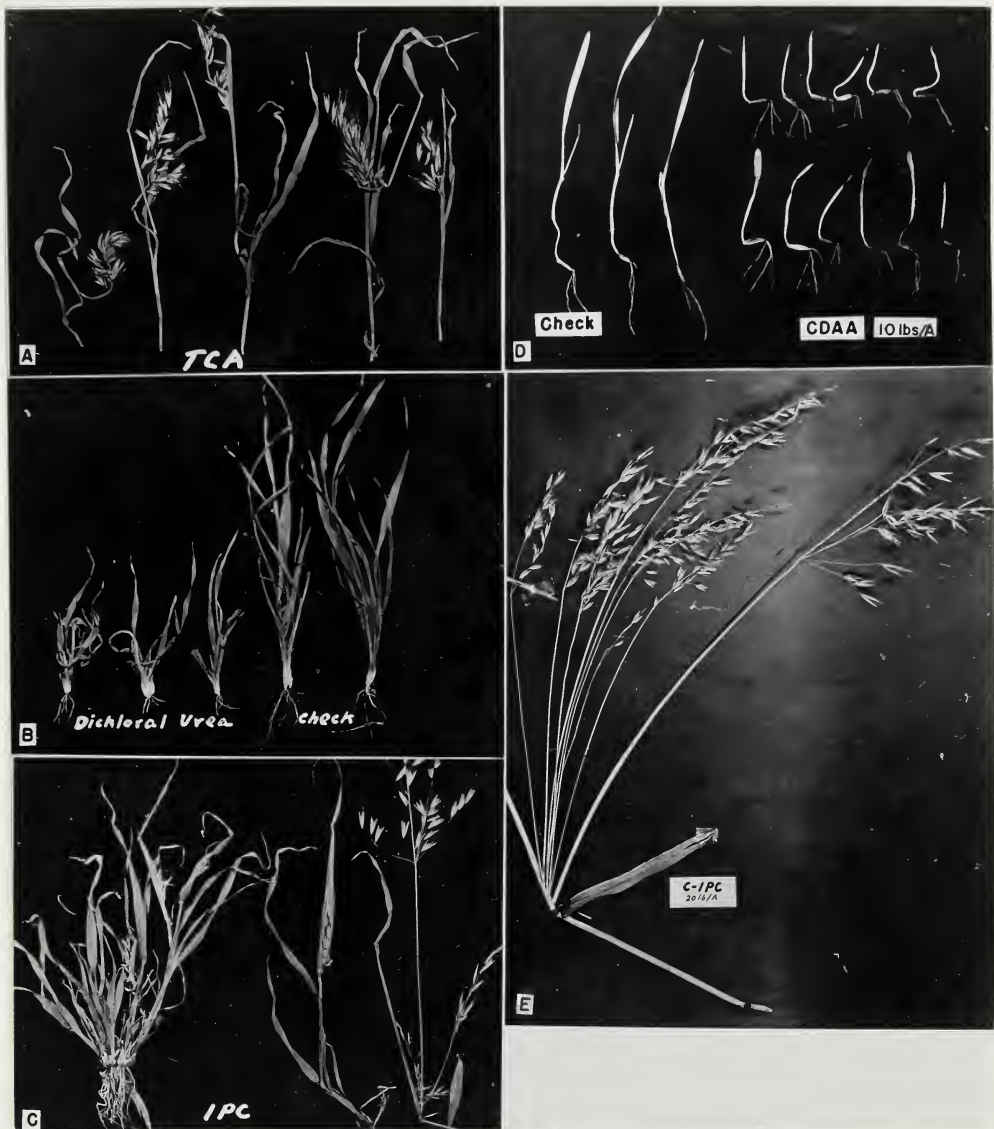


Fig. 7. Abnormalities in the growth of wild oats produced by pre-emergence applications of soil herbicides. A. Shortening of vegetative and panicle internodes from 40 lbs./A. of TCA. B. Stunting and deformation of seedlings from 20 lbs./A. of dichloral urea. C. and E. Multiple panicles from shot-blade node and other abnormalities induced with 20 lbs./A. of IPC and CIPC. D. Suppression of wild oat emergents with 10 lbs./A. of CDAA.

chemicals were also applied at 10 and 20 lbs./A., in a farmer's field, on June 16, 1953, to late seeded oats in the 2 - 3 leaf stage. A randomized block design, replicated three times was used. Since the field had a heavy infestation of wild oats, it was hoped that data could be obtained on the protective value of these herbicides under more favorable moisture conditions, against later emerging wild oats. Due to the late sowing date and the advent of warmer weather, no wild oat growth occurred, and the experiment was confined to observation of herbicidal effect on the crop. Visual damage was evident from Sesin but analysis of yield data did not show a significant reduction. DCU appeared to stimulate oat growth, causing a marked greening and healthy appearance of the foliage. No significant yield differences due to treatment were obtained, but protein analysis showed a significant increase in percentage of protein of the kernels from plots of both the 10 and 20 lb. rates of chemical treatment. This effect of the herbicide was of sufficient interest to be investigated further, and will be dealt with in a later section.

On June 2, 1954, CIPC, Alanap, and TCA were applied at the rates shown in Table X, to wild oats sown two days previously. Plant counts and green weight were obtained 89 days after spraying. Frequent precipitation during the germination and young seedling stages appeared to be optimum for chemical activity. However, there was no significant reduction in plant numbers from Alanap treatment, and this chemical significantly reduced green weight at only the 40 lbs./A. rate. Plant count was significantly

Table X. (Expt. 9) Effect of CIPC, Alanap, and TCA, sprayed June 2, 1954, on wild oats planted two days previously. Data are expressed as percentage of check, \bar{M} of 4 replications.

	Treatment lbs./A.									Check
	CIPC			Alanap			TCA			
	5	10	20	10	20	40	12.5	25	50	
Plant count	59*	50*	17*	98	91	86	79*	62*	66*	100%
Green weight	83*	70*	42*	96	90	83*	89	48*	40*	100%
L.S.D's @5% level: Plant count = 20.3; Green weight = 16.4.										

* Indicates a significant reduction at the 5% level.

reduced by all rates of CIPC and TCA, and green weight by all rates of CIPC, and by all but the 12.5 lbs./A. rate of TCA. The data show that CIPC was much superior to TCA, although applied at less than half the rate per acre. CIPC-treated plants exhibited a much weakened root system and were heavily lodged by rainstorms. A comparison of the plant-count and green-weight-data revealed interesting facts about these chemicals. TCA exerted its effect chiefly through stunting of growth and resultant reduction in green weight per surviving plant. While CIPC provided better plant kill at an early age, survivors were later able to grow normally and thrive under the reduced competition. This indicated that a green weight was a less reliable measure of CIPC effect than was the number of surviving plants.

Two new herbicides, Dalapon, and CDAA were tested in applications to soil in 1955. Dalapon, CDAA, TCA, IPC, and CIPC were applied at two rates, as shown in Table XI (A), on May 12,

Table XI. Effect of CIPC, IPC, Dalapon, TCA, and CDAA on plant count and green weight of wild oats planted before spraying the soil. Data are expressed as percentage of check, \bar{M} of 4 replications.

Treatment	Lbs./A.	Plant Count	Green Weight
<u>A. Expt. 12, Sprayed May 12, 1955</u>			
CIPC	10	34	38
	20	20	21
IPC	10	40	54
	20	29	36
Dalapon	10	90	10
	20	67	3
TCA	25	76	70
	50	68	47
CDAA	5	80	86
	10	45	78
Check		100%	100%
<hr/>			
L.S.D's @5% level		17.1	13.6
<hr/>			
<u>B. Expt. 14, Sprayed June 8, 1955</u>			
CDAA	0	100%	100%
	5	55	56
	10	19	22
<hr/>			
L.S.D's @1% level		37.9	29.3
<hr/>			

1955, one day after seeding wild oats. Plant-count and green-weight-data were obtained 72 days after seeding, when most plants were fully headed.

Dry soil conditions prevailing for one month after spraying reduced herbicidal effect, and only CIPC and IPC at the high rate gave over 70% mortality of wild oats. CIPC in this, as in other experiments, gave results superior to IPC and resulted in a green-weight-reduction in proportion to the decrease in plant numbers, whereas the weight per surviving plant increased slightly following IPC treatments. Dalapon behaved similarly to TCA by reducing plant number only by about 30% at the high rates, and acting chiefly by stunting of survivors. The stunting effect of Dalapon resulted in green-weight reductions of 90 and 97% at the 10 and 20 lb. rates, respectively. CDAA reduced plant numbers by over 50% at the 10 lb. rate, and like IPC, allowed survivors to increase in weight due to decreased competition. Wheat was sown in the harvested plot areas 80 days after spraying, to check for residual effects. Residual effect was evident at the time of wheat germination, even in plots treated with the 10 lb. rate of IPC and CIPC. Stunting of wheat from TCA and Dalapon remaining in the soil became evident some time later. It would be expected that these more soluble chemicals had been leached to a greater depth in the soil than the carbamates, and thus would not show residual effects until the wheat roots had penetrated deeper. Very little residual effect could be noted on a second wheat planting made 100 days after spraying.

CDAA was compared with another acetamide, CDEA, and with four dithiocarbamates, CDEC, 551-E, 552-I, and 553-T, in an application made on June 8, 1955, to the soil surface of plots in which

wild oats had been sown six days previously. All chemicals were applied at 2.5, 5, and 10 lbs./A. Almost one inch of rainfall occurred during the two week period following treatment, thus favoring chemical activity. There was no noticeable reduction in actual plant emergence from any treatment but all chemicals at the 10 lb./A. rate caused some stunting and malformations in the young seedlings (Fig. 7e). This effect was perhaps most pronounced from CDEA, but as growth proceeded, only the 5 and 10 lb. CDAA treatments resulted in visual reduction in plant numbers and green weight. Accordingly, all chemicals were classed as inferior to CDAA, and data were taken for only the effective rates of this chemical.

As shown in Table XIB, both the 5 and 10 lb./A. rates of CDAA resulted in highly significant reduction of plant numbers and green weight, with the effects of the 10 lb. rate distinctly superior to those from the 5 lb. rate. Unlike the results from CDAA in the previous experiment, green weight was suppressed in direct proportion to the number of escapes.

Effect of incorporation of chemical with the soil, and of precipitation, on wild oat control with CDAA and CIPC

The effect on wild oat control and wheat injury from CDAA at 5 lbs./A., and CIPC at 10 lbs./A., mixed into the soil, was tested using plots 6 x 10 ft. in size, arranged in a systematic design to facilitate rototilling or disking with a hand pushed garden disk. Four rows of wild oats and three rows of wheat were sown with a garden seeder. Seeding, spraying, and tillage

followed several definite sequences on June 28, 1955, as shown in Table XII. On the following morning two replicates were heavily irrigated from a hose, rendering the soil muddy at the surface and thoroughly moist to a depth of 3 - 4 inches. Two replicates were left dry. Unfortunately, for a comparison of chemical effect at two soil moisture levels, light rain fell in the afternoon, and several heavy rains totalling over two inches fell during the week following treatment. Visual observations at early growth stages, and examination of plant-count and green-weight-data taken 76 days after seeding, disclosed no differences between replications, and hence no effect from irrigation. From these results it would seem that CDAA and CIPC, both only slightly water-soluble, respond best under a certain optimum soil moisture level, and within limits are not greatly affected by amounts above this optimum.

Analysis of both plant-count and green-weight data for both species showed effects of the various treatments to be highly significant, and as shown in Table XII, differences between "incorporated" and "non-incorporated" treatments were significant for both chemicals. CIPC killed all wild oats and wheat when incorporated by rototilling or thorough disking, and was progressively less effective when lightly disked, disturbed by seeding or undisturbed. CDAA, at half the rate of CIPC, proved almost completely effective when undisturbed, and significantly less effective under all "incorporation." Wheat, on the other hand, was most vulnerable to well incorporated CDAA. This reversal of effect, between the two species, illustrated in Fig. 8, was extremely consistent between

Table XII. (Expt. 15) Effect on wild oat control and wheat injury from CDAA and CIPC left undisturbed at the soil surface or mixed with the soil.

Sequence of operations (June 28, 1955)	Plant count (% of check)				Green weight (% of check)			
	CDAA 5 lbs/A.		CIPC 10 lbs/A.		CDAA 5 lbs/A.		CIPC 10 lbs/A.	
	Wild Oats	Wheat	Wild Oats	Wheat	Wild Oats	Wheat	Wild Oats	Wheat
1. Untilled - seeded before spraying	2	38	25	121	3	65	50	142
2. Untilled - seeded after spraying	26	23	30	36	66	35	76	57
3. Sprayed - rototilled - seeded	33	4	0	0	42	2	0	0
4. Sprayed - disked 5 times - seeded	20	5	0	0	32	9	0	0
5. Sprayed - disked once - seeded	23	19	10	9	48	28	23	11
6. Check - seeded only	100%	100%	100%	100%	100%	100%	100%	100%
L.S.D's @5% level	13.2	16.3	13.2	16.3	21.1	29.0	21.1	29.0

replicates. A partial explanation may be associated with the faster germination and more extensive seedling root system inherent in wheat, and its contact with the incorporated CDAA, while the slower germination, and less extensive seedling root system of wild oats responded best to the movement of a more concentrated and undisturbed layer of chemical by heavy rains four and five days after spraying.

During the course of the experiment a fairly uniform infestation of broadleaved weeds appeared. Such striking control with CDAA was evident that plant-counts were made on the three main species at the time of their removal, 45 days after spraying. The three main species were common groundsel (Senecio vulgaris L.), prostrate pigweed (Amaranthus graecizans L.), and redroot pigweed (Amaranthus retroflexus L.). All CDAA treatments resulted in highly significant reduction of these species, and there were no significant differences due to tillage treatments. Under the conditions of high soil moisture which prevailed, there was, however, a trend towards better control of the more resistant redroot pigweed when the soil was undisturbed after spraying.

It is logical to expect that precipitation, following application of soil herbicides, would exert a maximum effect during sprouting and actual germination, and before the young emerged seedling attains a deep enough root system to penetrate beyond the contaminated soil layer. Accordingly, rainfall occurring during the first two weeks after chemical application



Fig. 8. Reversal of relative susceptibility to CDAA of wheat and wild oats, as a result of incorporation of chemical. In each plot the four rows on the left are wild oat plants, and the three rows on the right are wheat plants.

was plotted against wild oat survival, from the standard rates of "non-incorporated" CDAA and CIPC in three tests of each chemical. It can be seen from Fig. 9, that reduction of plant-count and green-weight by 5 lbs./A. of CDAA, was directly proportional to amount of rainfall. Although only two points are available for the 10 lb. rate of CDAA, the slope was the same as for the "5lb./A. plant-count" curve, but with the high rate giving 35% better kill under fairly dry conditions. With CIPC at 10 lbs./A., no direct correlation existed and conclusive results could not be drawn from the three point curve. From the meagre data, the trend appeared to be a somewhat increased control with heavier rainfall, followed by much less effect under very wet conditions. The "green-weight" curve for CIPC did not correspond well with the "plant-count" curve, and as discussed previously is probably a less accurate criterion of toxicity for a herbicide exerting its chief influence as a seedling toxicant rather than as a growth suppressor.

To investigate further the effect of soil moisture and incorporation of chemical with the soil, a late season test was started on August 29, 1955, with CDAA and CIPC both applied at 5 lbs./A. The soil had been loosely tilled but was moist enough from previous rains to promote good germination. Using a garden seeder, only wild oats were sown in the CIPC plots, while wild oats, wheat, barley, and flax were sown in the CDAA plots. Seedings were made at two depths (about one and three inches), before spraying on plots left undisturbed, and after spraying and rototilling, where incorporation of chemical was practiced. The

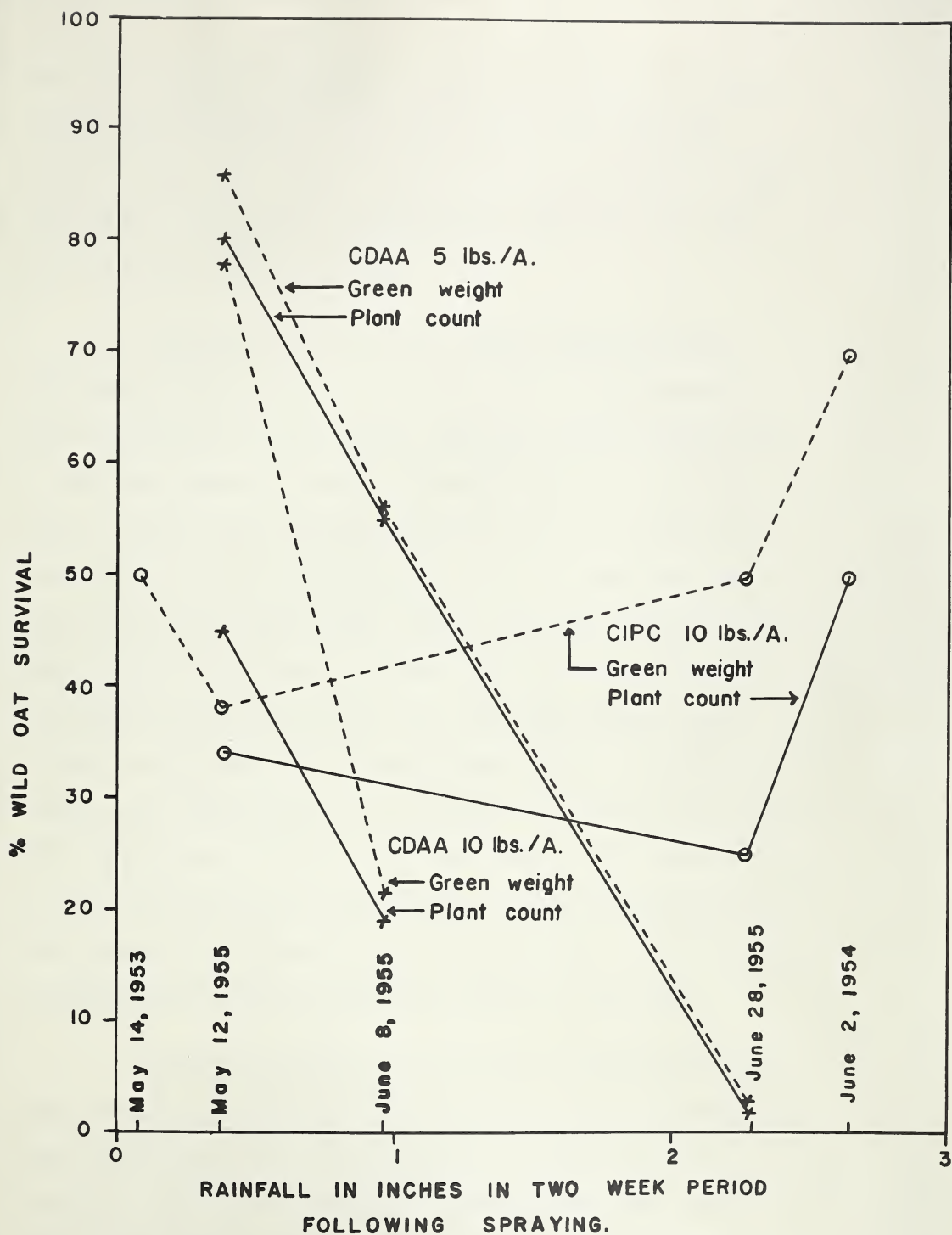


Fig. 9. Relationship between precipitation and degree of control with non-incorporated CDAA and CIPC.

Dates indicate day chemical applied.

test was conducted in duplicate, with one set of plots left dry, and the other heavily irrigated from a hose until free water remained on the soil surface and the soil was saturated to a six-inch-depth. The wild oats emerged in nine days, about two days later than the cereals and flax.

Observations 20 days after seeding indicated little difference between wild oat control with CIPC as influenced by depth of seeding or soil moisture level, but showed incorporation to give much superior control. On the dry CDAA plots, wild oat control was best with incorporation, but with the irrigated CDAA plots, tillage was not advantageous. Similar control resulted for wild oats from both depths. Barley and wheat were more resistant to CDAA than wild oats, and showed little injury except when the chemical was rototilled into the soil, then plants from the shallow seeding were the most suppressed. Injury to flax was most severe under incorporation and irrigation. As well as demonstrating that effectiveness of CDAA on wild oats can vary with distribution in the soil by tillage or precipitation, this experiment indicated that pre-emergence application to cereals and flax cannot be safely employed under conditions that favor control of wild oats.

Unreplicated applications of 0, 5, and 10 lbs./A. of CDAA and CIPC, in conjunction with tillage, were made on October 11, 1955, and May 14, 1956, to an area heavily infested by seed shattered from a wild oat stand. Spring-emergence showed that, with a given rate of either chemical, control was much superior

when seeds on the soil surface were sprayed directly, followed by incorporation with the soil, as compared with the spraying and incorporation of chemical after seeds had been rototilled into the soil. Dry weather prevailed after spring treatment, and poor control resulted when chemicals were not incorporated with the soil.

Following incorporation with the soil, fall applied CIPC gave over 90% control while the initial residual effect of fall applied CDAA (causing an estimated reduction in plant numbers of 30 - 60%) did not persist. Escapes and later growth thickened the stand to such an extent, that one month after spring emergence, no degree of control was evident on the plots that received fall applications of CDAA. Spring application and incorporation of CDAA, on the other hand, gave good results, delaying germination and suppressing growth to the extent that escapes were only 4 - 6 inches tall 60 days after emergence. Spring-applied CIPC gave somewhat poorer results than spring-applied CDAA, or fall-applied CIPC.

Laboratory experiments with herbicides for soil treatments

A. Germination following direct application of chemicals to wild oat and crop seed

After the harvest of a heavily infested crop, the ground is usually littered with recently dropped wild oat seed. Chemicals can be expected to be more effective if applied directly to the seed as it lies at or near the soil surface, immediately after harvest, than if applied later, when the seed has worked its way

into the soil or has been turned under by tillage. To simulate the early post-harvest condition, and to test herbicides under optimum conditions of moisture and position relative to the seed, 250 mature, primary, wild oat seeds, and also 50 seeds each of wheat, oats, barley, and flax were treated as follows. The seeds were spaced by means of a vacuum-operated seed counter, on the surface of several moistened layers of absorbant paper in germination trays. The trays, one per herbicide, were then sprayed, and placed in the germination cabinet to permit observation on germination of treated seeds. On April 5, 1955, IPC, CIPC, and Dalapon were applied at 5 lbs./A., and TCA and DCU at 20 lbs./A. An untreated tray of seeds was also germinated to serve as a control. A second test using IPC, CIPC, CDAA, CDEA, CDEC, 551-E, 552-I, and 553-T, all at 1 lb./A. was begun June 7, using the same methods and test conditions.

With herbicides applied to the soil to prevent weed emergence, the question arises whether sprouting is essential before the chemical can exert its effect or whether the chemical may enter the seed itself and kill directly, preventing all sprouting. To shed some light on this question, seeds were classified according to degree of germination and viability, as explained under materials and methods. The results of the germination tests are presented in Table XIII.

When the wild oat seeds which showed no external signs of sprouting (class III), were dehulled and placed into subclasses, it was seen that the number of seeds with complete dormancy

Table XIII. Germination of wild oat and crop seeds sprayed in germinator trays with soil herbicides.

Treatment*	Percentage of seed in the various germination classes												
	Wild Oats				Victory Oats		Thatcher Wheat		Montcalm Barley		Redwing Flax		
	I	II	IIIA	IIIB	IIIC	I	II	I	II	I	II	I	II
Test I													
IPC	0	60	7	17	16	0	58	0	38	0	62	0	94
CIPC	0	52	4	16	28	0	30	0	64	0	88	0	96
Dalapon	66	4	6	2	22	84	8	84	0	94	0	94	0
TCA	71	5	6	7	11	90	6	8	80	36	58	84	6
DCU	2	67	4	13	14	0	66	8	80	12	72	6	86
Check	79	0	5	14	2	91	0	99	1	95	1	100	0
Test II													
IPC	0	83	7	6	4	0	96	0	90	0	96	92	4
CIPC	0	84	4	8	4	4	74	0	98	0	98	96	0
CDA	26	61	6	2	5	90	4	64	36	96	4	94	4
CDEA	68	17	6	5	4	96	4	74	20	90	8	92	2
CDEC	82	6	5	2	5	90	10	90	4	86	8	90	6
551-E	33	52	3	8	4	81	14	4	78	84	8	94	0
552-I	80	9	5	2	4	92	4	84	6	88	6	98	0
553-T	58	29	5	4	4	94	0	84	14	92	8	96	0
Check	83	5	6	1	5	90	6	96	2	98	0	92	6

* In test I, IPC, CIPC, and Dalapon were applied at 5 lbs./A.; TCA, and DCU at 20 lbs./A.
In test II, all chemicals were applied at 1 lb./A.

(class IIIA) comprised only 3 - 7% of the total sample. In the first test, all herbicides resulted in varying percentages of seed which died with no evidence of having sprouted (class IIIC). No direct killing of wild oat seed was evident in the second test with chemicals applied at only 1 lb./A. Under the conditions of these tests, herbicide was present on the seed and in the available moisture during the period of inhibition. These conditions should have been optimum for entry of herbicide through the seed coat and for direct killing of the embryo. In addition, the stock of wild oat seed used possessed little dormancy. It has already been indicated (page 47), that solutes may enter a germinable wild oat seed more rapidly than a seed in the dormant state, due to a change in the degree of permeability of the seed coat with after-ripening. Under actual field conditions, due to the dormancy of seed, and dilution of even higher rates of chemical to a low concentration in the soil, direct killing of seed may be insignificant. If this be the case, only seeds germinating before residual effect of a chemical is dissipated would be susceptible.

Growth of seedlings from seeds germinating in a medium contaminated by herbicides is dependent on the efficiency and effective concentration of the herbicide. The stage at which individual seeds are affected would also be influenced by differences in the initial vigor of germination. Growth may cease before the expanding embryo penetrates the hull (class IIIB), soon after the appearance of the young seedlings parts from beneath the hull (class II), or stunting and abnormality may develop only

after an otherwise normal germination (class I). The appearance of representative seedlings from the second test, after five days of germinative conditions is shown in Fig. 10.

It may be seen from Table XIII, that under the conditions of these laboratory tests, IPC and CIPC at both the 1 and 5 lb./A. rates completely inhibited normal germination of wild oats, and only 2% escapes were present after treatment with 20 lbs./A. of DCU. Dalapon at 5 lbs./A. was slightly more detrimental to normal germination of wild oats than was 20 lbs./A. of TCA. Of the two acetamides, CDAA was more than twice as effective as CDEA, and 551-E was the most efficient among the four dithiocarbamates. Even under the optimum conditions of this experiment, Dalapon, TCA, CDEA, CDEC, 552-I, and 553-T could not be considered efficient seedling toxicants against wild oats.

The cultivated oats, variety Victory, were not dehulled and placed into subclasses of class III on concluding the germination tests, and as a result the extent of direct killing of the seed without sprouting could not be determined. Cultivated oats were of the same order of susceptibility to IPC, CIPC, and DCU, as were wild oats, but were much less affected at an early stage by all chemicals possibly in part due to their faster and more vigorous germination. Wheat, with its exposed seed coat was very susceptible to direct killing by all treatments in test I, in particular by IPC. IPC at 1 lb./A. resulted in some direct killing of wheat, whereas CIPC did not. With regard to class I germination,

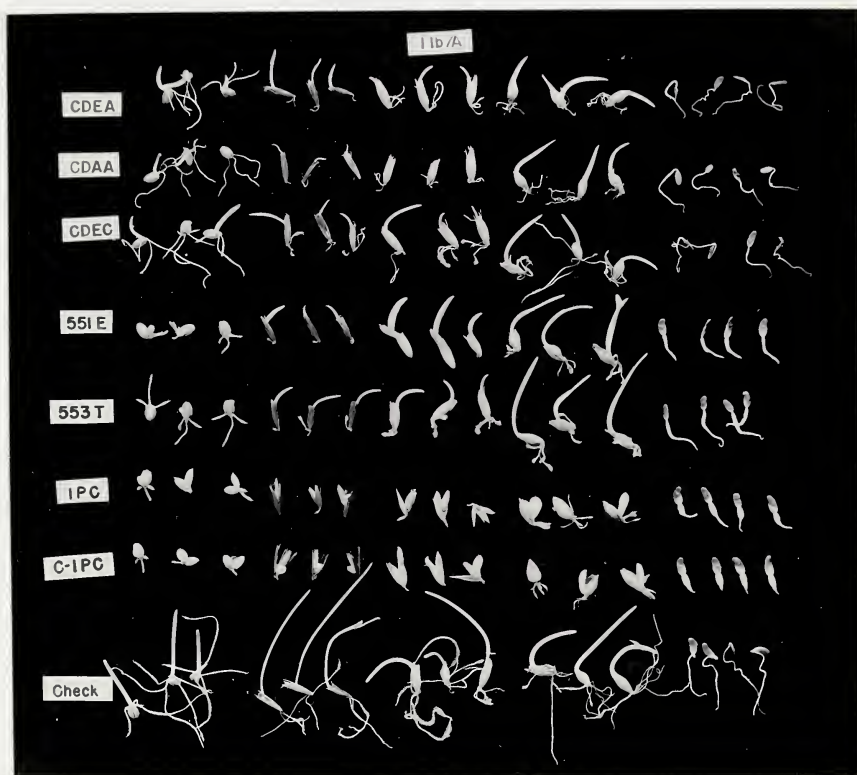


Fig. 10. Appearance of representative seedlings after five days under germinative conditions in the presence of herbicides. From left to right are three seeds each of wheat, wild oats, cultivated oats, barley, and four seeds of flax.

wheat seed was much more susceptible to TCA and 551-E, than was wild oats, but was somewhat more resistant to DCU, and had about twice the resistance to CDAA. The reaction of barley seed to direct herbicidal sprays followed the same pattern as wheat, but, in general, was less severe. No reduction in percentage of class I germination of barley resulted from CDAA, and treatment with 551-E allowed 84% normal germination as contrasted to only 4% for wheat. Direct killing of flax seed by herbicides was much less evident than for the cereals, while similar reductions in class I germination resulted from the 20 lb./A. rate of DCU, and the 5 lb. rate of IPC and CIPC.

Germination class I was considered of extreme significance since this class comprises the "escapes" from a treatment. Whether these escapes later thrive depends upon the persistence and degree of stunting or deformation from herbicides. In test I, Dalapon and TCA, though suppressing initial seedling growth of wild oats to only a very limited extent, exerted their effect later by preventing growth in the advanced seedling stages. In test II, measurements of wild oat and crop seedlings were taken to determine the mean shoot length of the escapes. The mean shoot lengths after 12 days of test are expressed in Table XIV as percentages of the mean shoot lengths of the untreated check. The mean shoot length of the check in centimeters is also given to provide a scale for comparison.

Table XIV. Suppression of shoot growth of wild oat and crop seedling escapes, from 1 lb./A. rates of carbamates, dithiocarbamates, and acetamides, sprayed directly on seeds in germination trays

Herbicide	Mean shoot length of class I* germinants (as % of check)				
	Wild Oats	Victory Oats	Thatcher Wheat	Montcalm Barley	Redwing Flax
IPC	-	-	-	-	deformed
CIPC	-	-	-	-	deformed
CDAA	30	21	26	31	normal
CDEA	50	65	36	48	normal
CDEC	40	29	56	64	normal
551-E	34	20	-	50	deformed
552-I	46	29	60	54	normal
553-T	48	54	26	80	deformed
Check %	100	100	100	100	normal
Check (cm.)	3.91	9.01	5.31	8.56	-

* See text.

As may be expected, the herbicides most effective in preventing normal germination were also the ones most effective in preventing further growth of seedlings that had escaped initial damage. The carbamates, IPC and CIPC, strongly inhibited root development and allowed formation of only very short, bulbous shoots in the cereals. In flax, these chemicals caused extremely distended hypocotyl regions of the seedlings (Fig. 10). The superiority of CDAA over CDEA was again demonstrated, as was that

of 551-E among the dithiocarbamates. There was no useful degree of tolerance evident between wild oats and the cereals, but the fact that flax seedlings were not harmed by CDAA and CDEA may offer some promise for the use of these chemicals under special conditions against wild oats in this crop.

B. Germination of wild oat seeds collected from the soil surface after spraying stubble with IPC

On October 5, 1954, 10 lbs./A. of IPC was applied to an area in which a heavy stand of wild oats had shattered seed on the soil surface. The area was later lost to construction, preventing any observations on natural germination the following spring. Samples of wild oat seed, however, from the treated, and adjacent untreated area were obtained from the soil surface 16 days after spraying, and stored loosely in seed envelopes in the laboratory. The soil was very dry at the time of spraying, and remained dry before seed collection, with the exception of light traces of rain and snow. This condition coupled with cool autumn weather presumably kept to a minimum the loss of IPC from the seed and soil surface. After an after-ripening period of 6 months, the treated and untreated seed was separated into mature, fully pigmented, and immature, white seed. A series of germination tests was conducted to assess the effect of direct IPC spray to the seed.

The results of germination tests I, II, V, and VI, given in Table XV, show tremendous reduction in normal germination (class I) of wild oat seed as a result of direct contact with IPC

Table XV. Effect from direct application of IPC at 10 lbs./A., October 5, 1954, on germination of wild oat seed shattered on the soil surface.

Description of test	No. of seeds	% in germination classed					% Sprouted
		I	II	IIIA	IIIB	IIIC	
<u>I - April 26, 1955 - Mature seed</u>							
IPC treated	450	14	32	10	20	23	66
Check	450	74	6	8	0	12	80
<u>II - May 17 - Mature seed</u>							
<u>IPC treated</u>							
with hull	50	10	40	8	26	16	76
dehulled	50	82	16				98
<u>check seed</u>							
with hull	50	78	4	10	0	8	82
dehulled	50	74	24				98
<u>III - July 21 - Residue test on hulls from dehulled seed of test II</u>							
50 IPC hulls	50*	0	68				68
50 check hulls	50*	42	28				70
<u>IV - August 9 - Above residue test repeated after autoclaving</u>							
50 IPC hulls	50*	92	6				68
50 check hulls	50*	76	10				86
<u>V - August 9 - Remainder of mature seed, plus residue test on hulls</u>							
<u>IPC treated</u>							
with hull	44	0	98	2	0	0	98
dehulled	43	89	9				98
<u>Residue test</u>							
43 IPC hulls	50*	0	88				88
43 check hulls	50*	76	14				90
<u>VI - August 9 - Immature seed</u>							
IPC treated	4 x 50	6	29	3	24	38	59
check	4 x 50	26	7	6	15	44	50

* In residue tests, 50 dehulled, untreated, primary seeds used as indicators of residue.

spray. IPC treated seed had only 0 - 11% class I germination, while the untreated check seed showed a minimum of 74% for mature seed and 28% for immature seed. Dehulling did not increase the germination of check seeds but when IPC treated seeds were dehulled, the number of class I seeds equalled that from the check. This suggested that IPC was localized on the hulls and had not penetrated to the actual seed coat, at least in amounts sufficient to inhibit germination. Comparisons of the total number of seeds sprouting (classes I, II, and IIIB) for sets of treated and untreated seeds, either with or without hulls, reveal little difference. Thus under the conditions of contact in this experiment, wild oat seed was not affected by IPC prior to sprouting.

Additional proof that the IPC was held tightly in or on the treated hulls was furnished by residue tests. Hulls from the dehulled seed of germination tests III, and IV were vigorously stirred with 5 ml. of water in a micro-homogenizer for a ten minute period. The homogenate was then distributed over two layers of filter paper in a petri dish and 50 dehulled, untreated seeds placed thereon. The IPC impregnated hulls completely inhibited germination of the untreated seeds as illustrated by Fig. 11.



Fig. 11. Inhibited germination of untreated wild oat seed after contact with residue held by hulls of IPC treated seeds.

Because of poor germination of check seeds in the first residue test (test III, Table XV), an additional test was made after sterilizing the petri dishes and hulls in an autoclave. The results (test IV) were extremely interesting in that residual effect of IPC had vanished, either as a result of dissipation during the previous test, or, more likely, from volatilization during autoclaving (240 - 250° F. for 15 minutes).

C. Dissipation of CIPC from wild oat seed and hulls

Following the experiment described above, in which IPC residue on wild oat hulls was shown to have persisted after more than ten months of seed storage, a series of tests was undertaken to investigate conditions likely to cause loss of carbamates from the seed. On August 18, 1955, CIPC was applied at 2 lbs./A. to wild oat seeds and hulls placed in a square yard spray area. Both whole and dehulled lots of mature, primary, wild oat seeds possessing little dormancy were used in the experiment, and in addition, hulls from previously dehulled seed. The "dissipation" tests with chemically treated hulls were made on 0.5 gram samples. Treatments included: 1. Placing seed or hulls in a Gooch crucible and washing for one minute in a heavy stream of distilled water. 2. Exposure to the atmosphere for various periods by suspending seed or hulls between layers of cheesecloth on a rooftop. The seed was spread thinly to allow free drainage of moisture and drying after precipitation. 3. Heating hulls in a forced air oven at 120° F. 4. Autoclaving hulls.

After the dissipation treatments, the seed was germinated using the folded paper towel method. Residue tests on the hulls were conducted in petri dishes as outlined in the previous experiment, with the exception that only 25 dehulled, untreated seeds were used as indicators of residue.

The results of the various dissipation treatments on the three classes of material are shown in Table XVI. Washing of untreated seed or hulls did not remove sufficient CIPC to allow any normal germination. Using the percentage of seeds showing slight germination (class II) as an indication of the relative amount of CIPC removed, it appeared that washing (or rainfall under field conditions) after the chemical had dried on the seed surface, only served to carry the chemical further into the hull as the seeds became soaked. The tenacity with which the hull retained the chemical was also shown by the residue tests on the treated hulls. The chemical was also tightly held by the seed coat proper, as indicated by the suppression of germinants from dehulled seed. It is possible that more prolonged washing of whole seeds would only serve to move the herbicide closer to the seed coat where it would be in a still more favorable position to inhibit germination.

Heating of Hulls for one hour or one day at 120° F. did not result in loss of CIPC in sufficient amount to allow normal germination of the indicator seeds in the residue tests. Autoclaving for five minutes likewise had no effect, while 15 minutes in the autoclave caused enough loss of CIPC from the hulls to

Table XVI. Dissipation of 2 lbs./A. of CIPC, sprayed August 19, 1955, directly to whole wild oat seed, dehulled wild oat seed, and wild oat hulls.

Dissipation treatment	% of seed in classes I & II		No. of seeds out of 25	
	Whole seed		Residue test on hulls	
	I	II	I	II
<u>Washed for 1 minute before germination test</u>				
Check	51	44	86	12
Treated - no washing after spraying	0	71	0	98
Treated - washed immediately	0	71	0	99
Treated - washed after drying 1 hour	0	47	0	100
Treated - washed after drying 1 day	0	48	0	100
<u>Exposure to atmosphere, August 20 - September 20</u>				
Check	86	3	53	8
Treated	5	69	0	73
Check - dehulled before germination test	93	5		
Treated - dehulled before germination test	55	38		
<u>Exposure to atmosphere, August 20 - November 19</u>				
Check	6	0	5	1
Treated	3	0	1	1
Check - dehulled before germination test	7	4		
Treated - dehulled before germination test	2	6		
<u>Heat treatment of hulls</u>				
1 hour at 120° F.			0	24
1 day at 120° F.			0	23
Autoclaved 5 min. (240 - 250° F.)			0	23
Autoclaved 15 min. (240 - 250° F.)			8	17

allow about one third normal germination of indicator seeds.

During the first month of exposure of the seed and hulls to the weather, light rain occurred on 11 days with a total precipitation of only 1.65 inches. The range in daily maximum temperatures during the period was 44 - 82° F. which should have favored a certain amount of volatilization of the chemical. That some dissipation of CIPC occurred was shown by a small number of normal germinants from treated whole seed, and by the residue test on treated hulls. Treated whole seed, dehulled before the germination test, produced more than half as many class I germinants as did the dehulled check, indicating that most of the CIPC was still localized in the hull. Considerable loss of viability of the dehulled seed occurred during the month's exposure. After three months of exposure the viability of both whole and dehulled check seed had dropped to less than 7%. That the additional exposure to the weather had caused further dissipation of CIPC, was indicated by the increasing proportion of treated seeds, as compared to the check, that did germinate.

As a further check on the CIPC residue remaining in the hulls after three months' exposure, residue tests were made on hulls obtained from the whole wild oat seed that had been dehulled before testing. In addition to the usual residue test using the total homogenate, tests were made on hulls filtered off after stirring, the filtrate from the latter, unstirred hulls, and autoclaved hulls. The results, given in Table XVII, indicate that

Table XVII. Residue tests on hulls from whole seeds exposed to the weather for three months after treatment with 2 lbs./A. of CIPC.

Type of residue test	No. of indicator seeds out of 25 in germination classes I & II			
	CIPC hulls		Check hulls	
	I	II	I	II
1. 50 hulls + stirring water	7	14	23	0
2. 50 hulls, filtered after stirring	11	11	23	0
3. Filtrate from <u>2.</u>	24	0	25	0
4. 50 hulls, not stirred	12	8		
5. 50 hulls, autoclaved	20	0		

considerable residue still remained in the hulls. That CIPC is not readily washed out of the hull is shown by residue tests 2. and 3. Even after violent stirring for ten minutes, the hulls did not release enough CIPC to inhibit germination of indicator seeds in the filtrate. When the hulls were not stirred, however, less inhibition resulted, presumably chiefly because the non-macerated tissue did not present as much surface to the indicator seeds. Autoclaving, as in previous tests, resulted in considerable loss of chemical.

Greenhouse experiments with CDAA

A. Influence of position of CDAA in the soil relative to that of wild oat seeds

To gain additional information on the influence of incorporation of CDAA with the soil on herbicidal effect, a greenhouse experiment was performed to afford a certain amount of

control over the position of the chemical in relation to planted wild oat seed. A greenhouse soil mixture (3 parts silty clayloam : 1 part sand) was moistened to a degree which would provide germination moisture yet allow handling, and minimize the need for watering in the initial period of the experiment. Two flats of six inch depth were half filled with soil and the soil sloped off diagonally from the bottom of one end to the top of the other. The soil was removed from the high end to a one inch depth, three rows of wild oats planted, and the soil replaced to restore the original slope. The two flats were then sprayed with 5 lbs./A. of CDAA. After spraying, the remainder of the flat was filled with soil to within one inch of the top, five additional rows of wild oats were planted, and the seed covered with one inch of soil. During the course of the experiment, one flat received a minimum of water, while the other was purposely overwatered in an effort to shift the location of the spray layer.

A pictorial view of the method, as well as the results, is given by Fig. 12. Emergence was uniform and complete for all rows of wild oats, but differences in growth soon occurred. All rows planted above the spray layer developed normal plants, as compared to check rows planted at the same time for another experiment. Emergents from seed located below the spray layer were completely suppressed. Growth of most of the seedlings did not extend past the coleoptile stage and all had died before photographing, 34 days after spraying and planting. At this time, one side was removed from the flats, and the roots carefully washed



Fig. 12. Influence of position of CDAA in the soil relative to position of wild oat seeds.

free from soil. The roots of all plants from seed located above the spray layer appeared normal, and penetrated to the bottom of the flat in all cases, indicating that root development was not affected by the distance of the seed above the spray layer.

Herbicidal effect and wild oat growth were identical for the two soil moisture levels, except for the first row of seed which was slightly less affected by CDAA in the lightly watered flat. For the first row, the initial location of the spray layer was at the soil surface, one inch above the seed. It appeared that CDAA was not leached into as favorable a position for suppression of the first row germinants in the lightly watered flat. Alternatively, in the event of equal concentrations of CDAA remaining at the soil surface in both flats, chemical activity

might be expected to be lower in the case of the dry surface soil. Both of these factors may contribute to make surface applications of CDAA less effective under dry conditions. Little information is available on the leachability of CDAA but it has been suggested that acetamides may be adsorbed by soil organic matter, and/or clay, and thus protected against loss by heavy rainfall (?). The low solubility of these compounds in water would also favor low mobility.

Assuming that the position of the herbicide did not change appreciably before germination, this experiment suggested that the action of CDAA is chiefly on the elongating seedling shoot, rather than by uptake through the root. Referring back to Fig. 10, illustrating the effect of direct application of 1 lb./A. of several herbicides to seed, it may be seen that CDAA allowed considerable root growth of wheat and barley but resulted in a high degree of shoot suppression. This is shown to an even greater degree in Fig. 7E, for wild oats treated in the field. These observations would tentatively suggest that the acetamides exert an effect opposite to that of root growth inhibitors such as the carbamates. Burrows (9), who had previously used this method with IPC and CIPC, did, in fact, find that wild oats were unharmed unless the chemicals were situated where they could be contacted by the growing roots. In his experiments, root growth from seed situated above the spray layer, initially was normal but ceased abruptly when the spray layer was contacted.

If CDAA acted on the seedling chiefly through the coleoptile or shoot, this might aid in explaining the reported high degree of selectivity between species, and some of the varied results obtained in field tests in which the chemical was either mixed with the soil or left undisturbed. The physiological mode of action of the acetamides is as yet unknown. Hamm and Speziale (18) have suggested that the activity per quantity of chemical is high enough to indicate enzymatic interference, or anti-metabolite activity at some critical point in the growing process.

B. Influence of time of treatment on effect of CDAA on wild oats, wheat, and barley

Wild oats, Thatcher wheat, and Montcalm barley were sown in separate, six-inch-deep flats in the greenhouse as follows: Rows containing ten seeds each were planted at about one inch depth, 24, 16, 12, 8, 4, and 2 days before spraying, immediately prior to spraying, and seven days (-7) after spraying, to give a range of seedling development, and time of emergence, relative to the date of spraying. When sprayed on December 12, 1955, the wild oat row sown 24 days previously was in the second leaf stage while the corresponding rows of wheat and barley were in the third leaf. Other stages of wild oats represented were: early 2nd leaf, 1st leaf, 1st leaf breaking from the coleoptile, emergence 4, 6, and 7 days later, and seeds not planted until one week later. For all dates of planting the wheat and barley were in a slightly more advanced stage than the wild oats. Flats of wheat and barley were sprayed with CDAA at 0, and 5 lbs./A., and flats of wild oats at 0, 2.5, 5, and 10 lbs./A. of CDAA.

The effect of treatment at various stages of development is illustrated by Fig. 13. Photographs taken 12 days after spraying, show that CDAA was far more toxic to seedlings emerging after spraying than to established seedlings. With the exception of the planting made one week after spraying, which was killed prior to emergence, death did not result until just after emergence. For the 5 lbs./A. rate, complete kill of wild oats was apparent at the time of photographing (Fig. 13A) for the "8, 4, 2, 0, and -7 day" dates of planting. At the same rate, only the "0", and "-7 day" wheat plantings, and the "-7 day" plantings of barley were completely killed. Severe stunting and malformations resulted in the escapes from the "4", and "2 day" wheat plantings, and to a greater degree in the "8, 4, 2, and 0 day" barley plantings.

The much greater susceptibility of wild oat germinants to CDAA, as compared to wheat and barley, was also evident in the emerged stages. As shown in Fig. 13A, wild oat seedlings in the first or second leaf suffered extreme tip burn from 5 lbs./A. Tip burn of wild oat leaves was almost as severe from 2.5 lbs./A., and almost complete leaf kill resulted from the 10 lb. rate of CDAA. That almost complete recovery of crop plants occurred is shown by the photographs (Fig. 13D, and E) of mature plants. Although the treated barley appeared somewhat stunted, heading was not delayed, while wheat, which showed less visible effect from the chemical, headed about four days later than the check. Only a few badly stunted, late maturing, wild oat escapes from the 2.5 lb. CDAA treatment produced panicles.

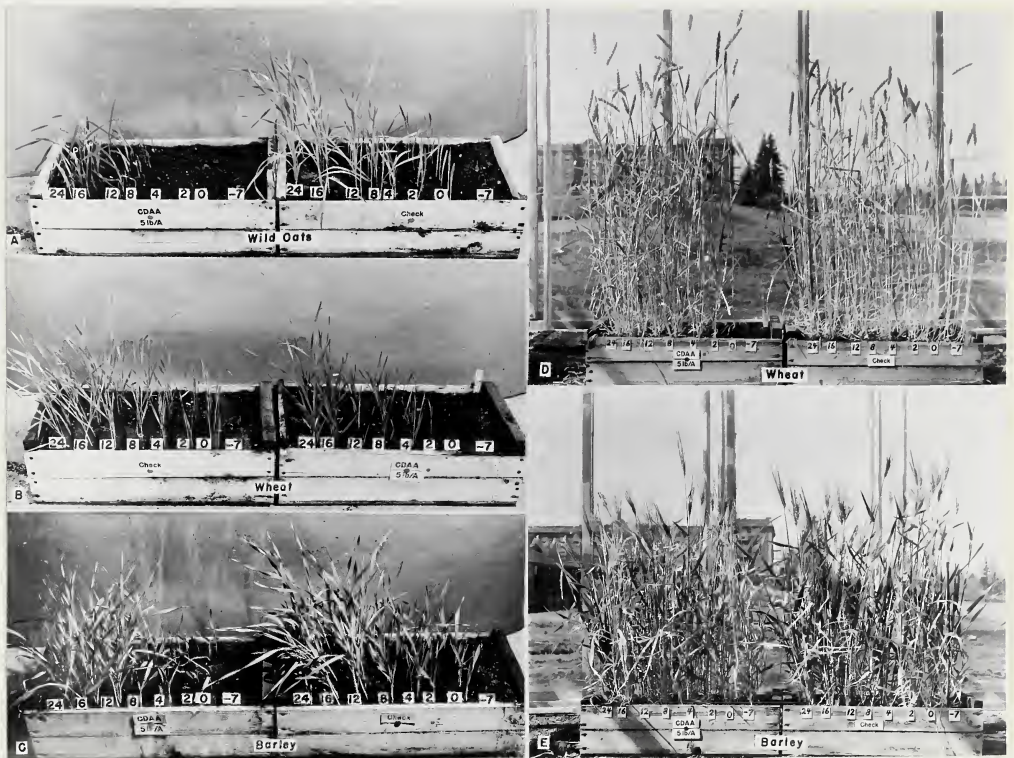


Fig. 13. Effect of 5 lbs./A. of CDAA sprayed on wild oats, wheat, and barley at various stages of plant development. A., B., and C. photographed 12 days after spraying. D. and E. photographed at maturity. The numbers along the flats indicate the number of days before (24, 16, 12, 8, 4, 2, 0), or after (-7) spraying when the respective rows were planted.

Under the conditions of this test in the greenhouse, promising selectivity was obtained. The results indicated that wheat and barley were most safely treated after the early second leaf stage, and that wild oats were most susceptible when sprayed not later than at the first sign of emergence. Since this difference in stage of development of crop and weed species commonly occurs in farm practice, there is basis for the hope that similar results from the chemical may be secured under field conditions.

RESULTS FROM APPLICATION OF HERBICIDES TO THE FOLIAGE

Preliminary greenhouse test

Prior to the 1953 field season, an unreplicated greenhouse experiment was conducted to gain preliminary information on the usefulness against wild oats, and on the mode of action of the most promising herbicides available at the time. Wild oats were sown in rows in flats, 39, 25, 18, 11, 7, 4, and 0 days prior to spraying to give a range in plant development ranging from the pre-shot blade stage to pre-sprouting. The following ratings were used to evaluate chemical injury:

- 0 - no visible effect as compared to check plants of the same planting date.
- 1 - no killing, some stunting.
- 2 - very little killing, severe stunting.
- 3 - good killing, but escapes normal.
- 4 - extensive killing, escapes seriously retarded.
- 5 - complete mortality.

In Table XVIII the ratings on injury at the various wild oat growth stages are given for the 16 herbicides used in the test. The results of field tests with the first seven herbicides listed in the table have already been discussed (pages 68 - 89). In this greenhouse experiment, no tolerant stage was evident for CMU, TCA, or IPC, though the greater effectiveness of this type of herbicide when applied before emergence was confirmed. With the exception of DCU which caused some stunting up to the second leaf stage, the other soil herbicides did not harm emerged seedlings. As a result of this experiment NIX (sodium isopropyl xanthate), and sodium cyanamide, were not field tested since they both caused some residual effect, and gave disappointing results, even at the high rates which were used. Compound B-405, the ethyl ester of alpha-cyano-beta-(2,4-dichlorophenyl) acrylic acid was of special interest as it had been shown to possess growth suppressing properties similar to maleic hydrazide (25). Although it gave only negative results in this test, it was retained for field testing because of its reputed qualities. For the remaining chemicals noted in the table, no residual effect was evident (with the exception of MH-salt), and excellent extent of killing of wild oat plants past the second leaf stage was obtained. The fact that residual effect was apparent from the MH-salt, while no residual effect occurred from the MH-amine, can probably be attributed to the freer entry of salts in soil solution through the roots. Residual effect may be expected to be much more severe in greenhouse experiments than in the field, since, in the greenhouse, both chemicals and roots are confined to a relatively shallow layer of soil.

Table XVIII. Ratings on herbicidal injury (five weeks after spraying) to wild oats sprayed at various growth stages in the greenhouse.

Herbicide & rate lbs/A.		Stage of wild oats when sprayed January 30, 1953							
		Just planted	Not yet emerged	Coleoptile emerging	1st leaf	2nd leaf	3rd leaf	5th leaf	
CMU	20	5	5	5	5	5	5	5	
TCA	50	4	5	5	4	4	4	4	
IPC	20	5	5	5	4	4	4	3	
DCU	20	2	2	2	2	1	0	0	
Herb. #1	10	2	2	0	0	0	0	0	
Sesin	10	1	1	0	0	0	0	0	
Alanap	10	0	0	0	0	0	0	0	
Sodium cyanamide	300	0	1	1	2	2	2	2	
NIX	20	1	1	0	0	3	3	3	
endothal	10	0	0	0	1	3	3	3	
MH. salt	10	1	1	1	4	4	4	4	
MH-amine	10	0	0	1	4	4	4	4	
B-105	10	0	0	0	0	0	0	0	
PCP	10	0	0	0	0	5	5	5	
DNBP(H ₂ O)*	5	0	0	0	1	5	5	5	
DNBP(oil)*	5	0	0	0	1	5	5	5	
Aromatic oil	20	0	0	0	0	3	4	5	

gal./A.

gal./A.

* DNBP(H₂O) - applied in 100 gal./A. of water,

DNBP(oil) - applied in 20 gal./A. of diesel oil.

The optimum results with contact herbicides and growth suppressors were obtained when the wild oat plants were in the second or third leaf stage. When seedlings in the emerging and first leaf stages were treated, there were many escapes, or if the seedling leaf was killed to the ground level, regrowth often occurred from the crown. The superiority of diesel oil over water as a carrier of DNBP may be partly attributed to diffusion of the oil solution down to the crown. In addition, the substituted phenols are thought to enter the foliage as undissociated molecules, and, as pointed out by Barrons (8), oil carriers can thus be expected to be more effective than water emulsions. Contact herbicides were also less effective when applied to more mature plants, such as those in the fifth leaf stage. The optimum stage for killing with contact herbicides thus corresponds to that for control by tillage. In actual farm practice, reliable control of wild oat growth by tillage is unlikely unless the operation is deferred until the second leaf stage.

Field studies with contact herbicides and growth suppressors

During the period of study, four experiments were conducted with herbicides sprayed on the foliage of young wild oat plants. The results of these experiments are given in Table XIX. Three of these experiments were conducted on seeded wildoat plots, while the other (Table XIX, B) utilized a natural farm infestation. For each of the experiments, the herbicides are arranged in the table in order of effectiveness, without regard for the varying rates at which they were applied. The control of wild oats, and

Table XIX. Effect of foliage treatment with herbicides, on green weight or plant count of wild oats, expressed as percentage of check (check = 100%). Data are the means of 3 replicates in B; 4 replicates for remaining experiments.

Herbicide and date of application	Type of data	Lbs. active ingredient/acre				
		2.5	5	10	20	40
<u>A. June 6, 1953 (2-3 leaf stage)</u>						
DNBP (in 20 gal./A. oil)	weight	8*	1*	2*		
MH-amine	"	64	31*	19*		
endothal	"		76	43*	25*	
aromatic oil**	"			75	59	22*
CIPC	"	76	63	19*		
IPC	"	87	73	14*		
Herb. #3**	"		71	74	56*	
PCP	"	84	76	55*		
MH-salt	"	88	84	47*		
Compd. B-405 & B-542***	"	92	96	96		
<u>B. June 16, 1953 (2-3 leaf stage)</u>						
Herb. #3**	count				38*	6*
aromatic oil**	"				54*	8*
DNBP (20 gal./A. oil)	"	26*	25*			
DNBP (5 gal./A. oil + water)	"	68*	30*			
MH-salt	data not taken		100	100	(approx. = check)	
<u>C. July 3, 1954 (3-4 leaf stage)</u>						
MH-amine	weight		39*	2*	2*	
DNBP (20 gal./A. oil)	"	41*	16*	10*		
dalapon	"	82	4*	2*		
endothal	"			48*	56*	19*
aromatic oil**	"			101	99	63*
<u>D. June 3, 1955 (2-3 leaf stage)</u>						
aminotriazole	weight			30*	5*	
dalapon	"		32*	12*		
MH-amine	"			55*	18*	
DNBP (5 gal./A. oil + water)	"		108	58*		
CDAA	"		104	102		
Aminotriazole	count			51*	29*	
MH-amine	"			64	22*	
DNBP (5 gal./A. oil + water)	"		82*	42*		
CDAA	"		114	86		
dalapon	"		106	117		

* - indicates a significant difference from the check at the 5% level.

** - for lbs. active ingredient/acre, read gallons of total chemical/acre.

*** - ester and amine of alpha-cyano-beta-(2,4-dichlorophenyl) acrylic acid, one half of plot to each formulation.

malformations which resulted from several foliage treatments are illustrated in Figs. 14, and 15.

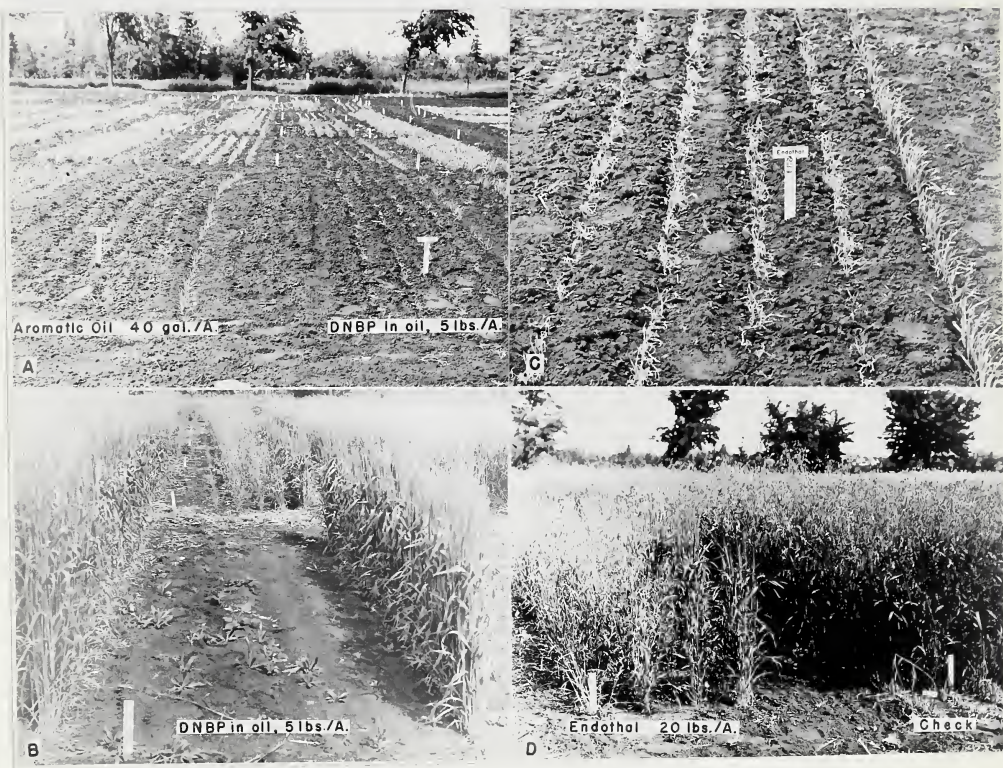


Fig. 14. Control of wild oats by foliage application of chemicals acting chiefly as contact herbicides which injure or kill rapidly. The right-hand row of each plot consists of wheat planted to emerge one day after spraying. There was no residual effect of contact herbicides on such wheat rows.

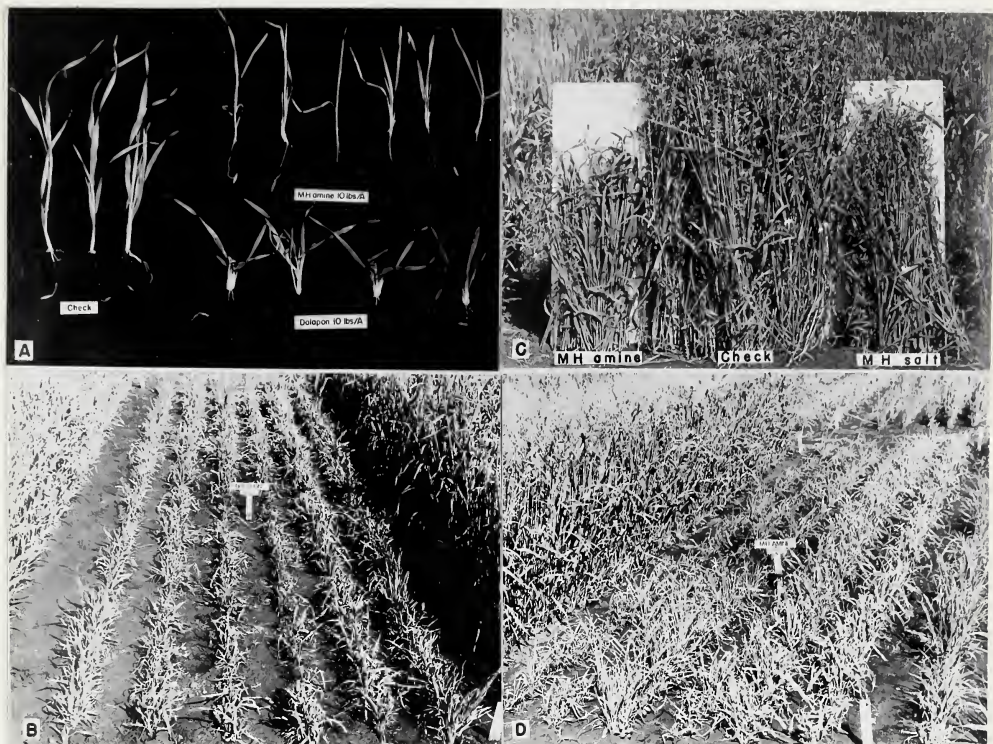


Fig. 15. Control of wild oats by foliage application of translocated, hormone type herbicides.

A. Stunting and onion leaf effect on seedlings from maleic hydrazide, and stunting, bulbous crown, and proliferation of tiller buds induced by dalapon treatment. B. Complete suppression of heading with 5 lbs./A. of dalapon. C. Comparison of the effectiveness of MH-amine, and MH-salt applied at 10 lbs./A. D. Complete suppression of heading with 5 lbs./A. of MH-amine. B. and D. consist of four rows of wild oats on the left, and two rows of cultivated oats on the right of the plots.

In the first experiment, the wild oat rows were sown May 12, 1953, and emerged 11 days later. Chemicals were applied on June 6, 14 days after emergence, when the wild oats were in the 2 - 3 leaf stage. To test for residual effect, a single row of wheat was planted to emerge one day after spraying. No residual effect of chemicals on the wheat was noted, except from IPC and CIPC. Only the DNBP (Dow General weed killer) resulted in significant reduction of the wild oat stand at the low rate. Applied with diesel oil as a carrier, the 2.5 lbs./A. rate resulted in a 92% reduction in green weight, while the 5 and 10 lb. rates gave 98 - 100% control (Fig. 14, A & B). The intermediate rate of only two herbicides, MH-amine, and endothal, with 70% and 50% control, respectively, gave significant green weight reduction. Endothal was characterized by rapid contact killing of leaves, almost to the ground level, but later regrowth from the crown resulted in many somewhat stunted escapes (Fig. 14, C & D). Plants that had not been killed to the ground level within a day of spraying with the contact herbicides had excellent powers of recovery, and with the exception of the plants stunted by endothal, were not noticeably delayed in heading. At effective rates, the action of maleic hydrazide was different. No immediate effect was evident, but with elapsed time it became obvious that growth of treated plants was not keeping pace with that of the check plants. In two to three weeks the leaves of the most seriously affected plants became necrotic and death ensued. The escapes from MH treatments made very slow growth with marked "onion leaf" effects, and

produced only a small percentage of panicles. Many of these panicles were abnormal and the seed poorly formed. The marked superiority of the MH-amine over the MH-salt is noteworthy. At both the 5 and 10 lb. rates the amine was more than twice as effective as the salt (Fig. 15C). Since the weather at the time of spraying was warm and dry, conditions were probably unfavorable for the absorption of the salt. Any chemical which was not absorbed may have been washed from the plants by a 0.14 inch rain falling two days after spraying. It has been shown by Smith et al., (35a), that the amine is absorbed much more efficiently than the salt, under conditions of low relative humidity.

It is of interest to compare the results from use of carbamates in this experiment, with those from applications to the soil surface 23 days previously for non-emerged wild oats (see Table IX). At the common rate of 10 lbs./A., the pre-emergence treatments gave only 50 and 45% control, while application at the 2 - 3 leaf stage gave 81 and 86% control, for CIPC and IPC, respectively. Since it has been well established that the carbamates are more effective on non-emerged wild oats, the exceptions as shown in these experiments were attributed to differing weather conditions. Only 0.08 inches of rainfall were recorded in the two week period following the pre-emergence applications, while 2.87 inches fell in eleven rainy days during the two week period following the foliage applications. As has been noted previously, the pre-emergence treatments of May 14, showed little activity until stimulated by rainfall 15 - 19 days after spraying. Thus in

both cases, the action of the carbamates would be chiefly on the roots of well established plants, with the pre-emergence applications at a disadvantage due to earlier loss by volatility under the intervening, dry, warm conditions. According to these results, it would seem feasible to treat wild oats emerged in a crop tolerant to carbamates provided suitable weather conditions for activity existed or were expected.

Following early observations on the above experiment with foliage sprays, some of the more promising herbicides were applied on June 16, to wild oats at the 2 - 3 leaf stage in a natural farm-infestation. The farmer - cooperator had left a small experimental area untilled while practicing delayed seeding for wild oat control, and had sown barley directly into the weed growth. It was intended to spray the wild oats just before crop emergence but rain prevented application until one day after first barley emergence. Barley seedlings were seriously damaged by all contact herbicides, but subsequent regrowth appeared to result in complete crop recovery with no delay in maturity.

A wild-oat-count made on August 10, when the wild oats were fully headed, showed a significant reduction for all treatments except for the MH-salt. Herbicide #3, and aromatic oil gave reductions of 94 and 91%, respectively, at the 40 gal./A. rate. Compared with the previous experiment, DNBP gave disappointing results, leaving 30 and 25% escapes with 5 lbs./A. with the low and high volumes, respectively, of diesel oil carrier. The 2.5 lb./A. rate of DNBP in the high volume of oil gave as good a control as

the 5 lb./A. rate. The poor results with the MH-salt, in spite of high humidity at the time of spraying, may be attributed to loss from the foliage by heavy rain soon after treatment. Herbicidal control in this farm test involving ^{the} contact pre-emergence method, assessed by visual comparison with the number of wild oat plants in the adjacent field area, showed that only the high gallonages of aromatic oils compared favorably with the standard delayed seeding method of control by tillage.

In the 1954 experiment with foliage treatments, MH-amine gave almost complete control of wild oats at 10 and 20 lbs./A., while only 82% reduction in green weight was obtained after use of 20 lbs./A. in the 1955 test. DNBP applied with 20 gallons of diesel oil per acre in 1954 gave 84 and 90% reduction in green weight with 5 and 10 lbs./A., respectively, while results were far from satisfactory with the water and oil emulsion used in 1955. It is probable that application with the low volume of oil would have resulted in better control if it had not been diluted to spray volume with water, but this could not be satisfactorily tested with the spray equipment and nozzles at hand. The activity of the dinitro compounds has been shown to increase with higher air temperatures (8, 14, 27). The maximum air temperature on the day of spraying, for the four experiments listed in chronological order in Table IX, were 72, 65, 66, and 62° F., respectively. This temperature difference may be partly responsible for the superior results with DNBP in the first experiment and the poor results in the fourth.

Dalapon, used for the first time in the 1954 foliage experiment, resulted in 76 and 98% reduction of green weight at 5 and 10 lbs./A., respectively, but gave only 68 and 88% control at the same rates in 1955. Almost identical reduction in green weight was obtained with a common application of 10 lbs./A. in the 1955 foliage test and in a soil treatment with non-emerged wild oats conducted 22 days earlier (see Table XI). No actual killing of wild oat plants resulted from foliage application, and as illustrated in Fig. 15, A & B, effect of Dalapon was manifest as extreme stunting, proliferation of tillering throughout the season, and the almost complete absence of normal panicles.

In the 1954 experiment, two rows of cultivated oats were planted at the same time as the wild oats. The much faster initial growth of the cultivated oats as compared to wild oats, resulted in a different physiological age at the time of spraying. Thus a direct comparison of the susceptibility of the two species to herbicides could not be made. With the greater amount of foliage presented to the sprays, however, cultivated oats were affected less by the contact herbicides, similarly affected by Dalapon, and were more susceptible to maleic hydrazide, as compared with the responses of the shorter wild oat plants. Typical maleic hydrazide and Dalapon effect is shown in Fig. 15, A, for wild oats in the juvenile stage, and in Fig. 15, B and D, for wild oats and cultivated oats at the time when check plants were fully headed.

Amino-triazole, applied as a foliage spray in the 1955 experiment (Table XIX D), rapidly caused the development of

chlorosis, followed by death or stunting. Very few of the most seriously stunted plants recovered sufficiently to produce panicles. Plant count at harvest time showed a 51 and 25% survival in the 10 and 20 lbs./A. plots, respectively. These survivors produced a green weight yield of only 30 and 5% of the check. The results from CDAA confirm those from the greenhouse tests discussed previously, in that CDAA is not effective as a foliage spray on established plants. A trend towards a reduced number of wild oat plants associated with the high rate was not significant, and there was no reduction in green weight or delay in heading.

Induction of seed sterility in maturing wild oat plants
by means of maleic hydrazide treatment

When a heavy stand of wild oats comes into head in a grainfield, it may be assumed that most of the yield reduction suffered by the current crop has already taken place. Of equal importance and concern is the fact that the wild oat plants will shatter large quantities of seed before the crop can be harvested, adding to the soil infestation and making repetition of current losses a certainty in following crops. Some hope of protection against this menace was offered by the finding by Knowles (22), in 1952, that seed sterility of wild oat and crop plants could be induced by maleic hydrazide sprayed after heading, and that a degree of selectivity existed. The following year, Carder (10) conclusively showed that germination of wild oat seeds could be reduced to 0 - 2% when sprayed at the milk stage with as little as 8 ounces of MH per acre. The germination of crop seeds was

also most sensitive at the milk stage, but the phasic development of early maturing Olli barley was sufficiently ahead of the wild oats to permit selectivity. As summarized in Table VII, there have since been many relatively successful trials of this method in the wild oat problem area.

The method was tried at Edmonton on a limited scale in 1955 to determine if differences in maturity of plants within a wild oat stand would seriously interfere with the success of the method, and to check whether MH-induced inhibition was permanent, or whether the seeds were forced into a yet more prolonged dormancy.

Single rod row plots of wild oats were sown two feet apart, and separated by a buffer row of Thatcher wheat. The experiment was conducted in duplicate with provision made for three dates of spraying at 0, 4, 8, and 12 ounces/A. of MH-amine, applied in 25 gallons of water per acre. Emergence of wild oats took place on May 23, 12 days after seeding. Since considerable tillering of wild oat plants occurred, early and late tillers resulted in all stages of development at spraying time. Forty-nine days after emergence, early heading was in progress, and all panicles that had emerged were tagged. At this date, all earlier maturing spikelet positions had been fertilized, and the seeds of the top whorls, and many of the seeds in the outside spikelets were in the advanced kernel forming stage. The first MH spraying was conducted one day later, followed by a second and third at weekly intervals. Intermediate heading panicles and late heading panicles were tagged just prior to the second and third sprayings. These tagged panicles of

the three age classes were harvested separately as they became mature, and before shattering was general. In addition, a bulk harvest was made of all panicles that had matured prior to or about the same time as the intermediate panicles, and also a bulk harvest of late panicles. Under these extreme conditions of tillering, plants matured over almost a four week period. The approximate relative maturity at the time of spraying, for the three tagged samples, and the time in days between various growth stages are given in Table XX.

Table XX. Relative maturity of early, intermediate, and late wild oat tillers when sprayed with MH, and time in days between various growth stages.

	Early tillers	Intermediate tillers	Late tillers
Days from emergence to heading	49	57	64
Days from heading to milk stage	8	7	7
Days from heading to harvest	20	20	22
Stage when sprayed July 12	kernel forming	shot blade	pre-shot blade
Stage when sprayed July 19	milk stage	kernel forming	shot blade
Stage when sprayed July 26	soft dough	milk stage	kernel forming

After harvest of the various samples, the panicles were put through a small plot thresher, and the seed of the tagged samples hand-sorted into mature, primary and secondary seed, and immature primary seed. A preliminary germination test on the intermediate and late, bulked samples was begun on October 7, using two - 50 seed lots per treatment from each replicate. These seeds were placed

in a cold room at 4° C. for the first six days of the test, after which they were transferred to the germination chamber at 20° C. The main germination tests were conducted in March and April of 1956. As a result of dry storage in the laboratory, the seeds were well after-ripened, and no cold treatment was required to obtain good germination of check seeds. Where possible, two - 50 seed lots were used per test, but with some lots of mature secondary, and immature primary seeds, especially from the late tagged sample, the number of seeds fell to 50 or less. The results of the spring germination tests on the tagged panicles, and a comparison of the October and April tests on the bulked intermediate maturing samples are given in Table XXI. Since treatment was not effective in the late bulked sample, and the 4 oz./A. rate of MH in no case reduced germination below 75% of the check, these data are not included in the table.

As shown in Table XXI, results from the three dates of spraying varied greatly with the relative maturity of the various samples. Germination tests on the mature primary and secondary seeds from the early panicles, suggested that they had not yet developed sufficiently at the time of the first spraying for optimum results, and were in too advanced a stage of kernel development at the third date of spraying. The greatest degree of induction of sterility resulted from the second date of spraying when most of the seeds in these panicles were in the milk stage. For the immature seed of the early sample, mostly originating in the later maturing lower whorls, similar results were obtained with both the second and third dates of spraying. The tagged samples

of intermediate maturity were slightly more than a week later than the early panicles, and their seed most affected by the third date of spraying. As indicated by the April germination test, the seed of the intermediate bulked sample was also most affected by the third date of spraying. The seed of the late, tagged sample were not sufficiently developed for satisfactory induction of sterility, even at the last date of maleic hydrazide treatment.

The above results well illustrate the difficulties that might be encountered due to extreme unevenness of maturity in a wild oat stand. Under the conditions of the experiment, the optimum spray date for induction of sterility of the largest number of seeds may have been situated somewhere between the second and third dates of spraying, probably about 60 days after the emergence of the wild oats. Examination of infestations in grainfields around Edmonton indicated that the extreme unevenness of maturity encountered in the experiment would seldom occur when wild oats were in competition with grain crops. Wild oat plants in the grainfields examined did not produce more than three tillers and matured quite evenly. Only under more open grown conditions in potato fields were wild oats observed to produce an abnormal number of tillers with resultant unevenness of maturity. In the majority of barley fields examined, the barley kernels were sufficiently ahead of the wild oat kernels in development to permit a degree of selectivity if they had been sprayed with maleic hydrazide.

A comparison of germination tests on aliquots of the bulk samples of panicles of intermediate time of maturity, conducted in

October, two months after harvest, with germination tests of the same samples, made in April, eight months after harvest, reveal an important change in effect of treatment with time. Whereas the germination of the check samples increased with time, due to after ripening, germinability of treated samples was markedly reduced. In the last two columns of Table XXI, germination of these treated samples is expressed as a percentage of that of the untreated check. This method of expressing the data facilitated a direct comparison between the fall and spring germination tests, and indicated that spring germination of the optimally treated samples had fallen to less than half of that in the fall. Friesen (17), at the Lacombe, Alberta, Experimental Farm had obtained similar results with seed treated with maleic hydrazide in 1954. His fall germination tests in soil in the greenhouse indicated markedly less favorable results from treatment than did germination tests on this seed conducted the next summer by the Plant Products seed laboratory at Calgary. This effect of rapid loss of viability of treated seed is perhaps not surprising in the light of morphological effects on the embryo itself, as will be discussed below.

The preliminary germination tests, conducted in October, had indicated only a moderate degree of induction of sterility. Thus it appeared at the time that the material would not be suitable for the second objective of the experiment, namely, to determine if inhibition of germinability due to MH treatment was permanent, or merely an induced lengthening of the period of natural dormancy. To aid in this study, samples of seed were made available

by Dr. Carder from some of his most effective 1953 treatments, conducted at the Beaverlodge, Alberta, Experimental Station (10).

Some of the Edmonton samples showing the greatest inhibition of germination by MH treatment were subjected to the 2,3,5-triphenyltetrazoleum chloride test for seed viability. Seeds were soaked in water overnight to activate their enzyme systems, then placed in 0.1% tetrazoleum solution for a period of 24 hours. Treated seed stained as readily as untreated seeds, indicating that the dehydrogenase systems of treated embryos were still active, and the seed still living, but normal germination somehow prevented. While the tetrazoleum test was not a measure of germinability of the treated samples, it did facilitate observation by staining and differentiation of the embryo tissue.

When the Beaverlodge seeds were tested in this way, large numbers of the treated seeds were only weakly stained, or were unstained. Longitudinal bisection of these seeds revealed that embryos were disorganized or absent. In addition, most of the strongly stained embryos were smaller in size than the controls, and disorganized to the extent that normal germination would be impossible. The range in embryo development of Beaverlodge seeds from the 8 oz./A. MH treatment, as contrasted to that of the untreated check, is illustrated by Fig. 16. No visible differences in embryo development had been noted in the earlier tests with Edmonton material. A re-examination with accurate measurement aided by the use of an ocular micrometer and dissecting microscope, revealed a slight reduction in embryo size due to the MH treatment.



Fig. 16. Embryo development following maleic hydrazide treatment of wild oat plants in the milk stage of kernel production. Upper row, check seeds with normal embryos. Lower row, seeds from 8 oz./A. MH treatment; embryos are disorganized or absent.

It is probable that this reduction in size would be accompanied by a rapid loss of vitality as previously noted. Of even more importance than reduction of embryo size would be a disorganization of embryo parts, not readily detected under the low magnifications used. Secondary seeds showed the greatest reduction in embryo size and six seeds out of 25 had disorganized embryos. The results of these tests with Edmonton and Beaverlodge wild oat seeds are summarized in Table XXII.

Additional proof that the inhibition of germination is permanent is furnished by the investigations of Mericle, Eunus,

Table XXII. Tests indicating permanency of maleic hydrazide induced inhibition of germinability of wild oat seeds*

MH oz./A.	% germination		Tetrazoleum reaction			Morphological effect on embryo
	Class I	Class II	Deeply stained	Weakly stained	No. of seeds	

1953 Beaverlodge wild oats, treated 78 days after seeding flax

check	86	-	45	0	5	bisection of seeds revealed embryos of most treated seeds, were extremely small, disorganized or absent
8 oz.	0 - 2	-	31	8	11	
16 oz.	0 - 2	-	19	8	23	
24 oz.	0 - 2	-	25	8	17	

1955 Edmonton seeds, from Intermediate maturing panicles, treated 64 days after emergence

Mature primary seed	Embryo size mm. **			
	A		B	
	\bar{M}	Range	\bar{M}	Range

check	93	0.5	25	0	0
12 oz.	2	42	25	0	0

Mature secondary seed

check	52	2	25	0	0
12 oz.	6	42	20	3	2

* Excepting Beaverlodge germination tests, all tests conducted March - April, 1956. Weak, abnormal germination (class II) of many treated seeds showed fair shoot growth but reduced, knobby roots, indicating much of the effect of MH was localized in the radicle.

** A - Total length of embryo including scutellum. B - Length from coleorhiza tip to coleoptile tip. Measurements were on 25 seeds excepting treated secondary where 6 seeds showed disorganized embryos and could not be measured.

and Mericle (28), into the possibility of using pre-harvest MH treatments to prevent sprouting and improve the storage of cultivated oats. These workers sprayed cultivated oats with a wide range of MH concentrations at four days after fertilization. Detailed histological examinations were made on oat kernels collected and killed and fixed 4, 8, and 15 days after spraying. Lower concentrations of MH were found to interfere with cell division, causing a reduction in cell numbers accompanied by precocious maturation of the individual cells. Higher concentrations caused complete disruption of normal differentiation. The extent of the effect was found to be a function of the concentration of MH, and of the stage of embryonic development at the time of treatment. Younger embryos appeared to be more affected than older ones, and embryos in an "intermediate" stage of development showed a differential effect, with the roots more severely affected than the shoots. This was attributed to the radicle being "ontogenetically younger", and thus more susceptible to the effects of maleic hydrazide. This differential effect was also noted during the germination tests of the present study. Many germinants possessed almost normal shoots but had little root development as a result of the treatment.

Miscellaneous Studies

Effect of Dalapon applied to plants at various growth stages, on the straw and grain yield of cultivated oats, flax, and rape

Victory oats, Redwing flax, and Argentine rape were sown May 31, 1954, as separate experiments to check the feasibility of selective control with Dalapon, of wild oats in the oil seed crops.

Cultivated oats were substituted for wild oats in this experiment since it was not desired to infest the available plot area, and because of greater ease in measuring grain yield of cultivated oats. The two species of oats treated at the 3 - 4 leaf stage in another experiment in 1954 had reacted similarly to Dalapon (see page 122). For each crop, a split plot design provided for six dates of treatment as whole plots, with 0, 1.5, 3.0, and 6.0 lbs./A. applications of Dalapon as split plots. The stages of crop development relative to dates of Dalapon application are summarized in Table XXIII.

Following harvest, the plot samples were air dried, and threshed. Straw weight was obtained by deducting the weight of grain from the air dried weight of the total plot sample. Yield data on straw weight for the three crops are given in Table XXIV, and seed yield data in Table XXV. Due to the small size of seed samples of flax and rape, bushel weight could not be obtained. The bushel weight data for cultivated oats, given in Table XXVI, could not be subjected to statistical analysis, since Dalapon treatments had reduced the yield to the extent that bushel weights for several plots could not be obtained. Killing frosts occurred on September 17, and 20. Since Dalapon delayed the maturity of crops (especially oats), the frost had a more serious effect on treated plots than on check plots. This lowered the seed quality and hence the yield, and may be considered as a secondary effect of the herbicide. In most years, earlier seeding would be possible, to escape the effect of adverse weather superimposed on actual herbicidal effect.

Table XXIII. Stages of crop development and dates of Dalapon application

Date	Days after emergence	Treatment stage	Crop development stages
<u>Victory oats</u>			
May 31	-11	--	Date of seeding
June 2	-9	I	Pre-emergence spray - 2 days after seeding
June 11	0	--	General crop emergence
June 12	1	II	Very young seedlings
June 19	8	III	2 - 3 leaf stage
July 6	25	IV	Well established plants
July 23	42	V	Shot blade
August 20	70	VI	Fully headed, 5 - 6 days past anthesis
October 1	112	--	Date of harvest
<u>Redwing flax</u>			
May 31	-17	--	Date of seeding
June 2	-15	I	Pre-emergence spray - 2 days after seeding
June 17	0	--	General crop emergence
June 19	2	II	Cotyledon stage
July 6	19	III	Well established plants
July 23	36	IV	Buds plentiful, some flowering
August 6	48	V	Advanced flowering
August 21	65	VI	Relatively few flowers
October 5	110	--	Date of harvest
<u>Argentine rape</u>			
May 31	-9	--	Date of seeding
June 2	-7	I	Pre-emergence spray - 2 days after seeding
June 9	0	--	General emergence
June 11	1	II	Cotyledon stage
June 19	9	III	Well established plants
July 6	26	IV	Pre-budding stage
July 23	43	V	Buds plentiful, flowering strongly
August 21	72	VI	Plants past flowering peak, badly lodged
September 22	104	--	Date of harvest

Table XXIV. Effect of Dalapon on straw yield of oats, flax and rape

Data: 2-rod row samples, \bar{M} of 4 replicates

Straw weight - kilograms						Straw yield as % of check		
Crop and treatment stage	lbs./A. of Dalapon				\bar{M} stages	lbs./A. of Dalapon		
	Check	1.5	3.0	6.0		1.5	3.0	6.0
<u>Oats</u>								
I	1.51	1.50	1.68	1.26*	1.49	99	111	83*
II	1.62	1.68	1.70	1.63	1.66	104	105	101
III	1.81	1.64	1.77	1.40*	1.65	91	98	77*
IV	1.74	1.79	1.83	1.05*	1.60	103	105	60*
V	1.45	1.63	1.76	1.74	1.64	112	121	120
VI	1.51	1.52	1.48	1.42	1.48	101	98	94
\bar{M} rates	1.61	1.63	1.70	1.42*		101	106	88*

L.S.D's @5% rates = 0.16, S x R = 0.36

Flax

I	0.79	0.73	0.69	0.66*	0.72	92	87	84*
II	0.81	0.73	0.84	0.75	0.78	90	104	93
III	0.82	0.85	1.05	0.89	0.90	104	128	108
IV	0.81	0.83	0.99	0.98	0.90	102	122	121
V	0.78	0.79	0.76	0.89	0.80	101	97	114
VI	0.76	0.82	0.90	0.83	0.83	108	118	109
\bar{M} rates	0.80	0.79	0.87	0.84		99	109	105

L.S.D's @ 5% stages = 0.09, S x R = 0.11

Rape

I	1.94	1.98	1.96	1.84	1.93	102	101	95
II	1.83	2.10	1.86	2.02	1.95	115	102	110
III	1.95	1.83	1.95	1.80	1.88	94	100	92
IV	1.93	1.92	2.01	1.87	1.93	100	104	97
V	1.88	1.82	1.92	1.92	1.89	97	102	102
VI	1.89	1.85	1.93	1.76	1.86	98	102	93
\bar{M} rates	1.90	1.92	1.94	1.87		101	102	92

L.S.D's - no significant differences

* Indicates significant difference from respective check.

Table XXV. Effect of Dalapon on seed yield of oats, flax and rape

Data: 2-rod row samples, \bar{M} of four replicates

Crop and treatment stage	Seed yield in grams				\bar{M} stages	Seed yield as % of check		
	lbs./A. of Dalapon					lbs./A. of Dalapon		
	Check	1.5	3.0	6.0		1.5	3.0	6.0
<u>Oats</u>								
I	601	730	415*	164*	478	121	69*	27*
II	720	748	522*	140*	532	104	72*	19*
III	766	575*	432*	161*	484	75*	56*	21*
IV	635	649	281*	32*	399	102	44*	5*
V	625	718	598	231*	543	115	96	37*
VI	585	658	560	548	588	112	96	94
\bar{M} rates	655	679	468*	213*		104	71	32

L.S.D's @5% rates = 132; stages = 92; S x R = 148

Flax

I	529	490	454	224*	424	93	86	42*
II	510	399*	216*	68*	298	78*	42*	13*
III	574	488*	242*	88*	348	85*	42*	15*
IV	510	401*	196*	40*	287	79*	38*	8*
V	516	456	305*	172*	362	88	59*	33*
VI	475	512	411	431	458	108	86	91
\bar{M} rates	519	458	304*	170*		88	59*	33*

L.S.D's @ 5% rates = 91; stages = 54; S x R = 84

Rape

I	235	286	285	196	250	122	121	83
II	212	281	201	176	218	132	95	83
III	249	230	242	171*	223	92	97	69*
IV	260	249	220	109*	209	96	85	42*
V	296	228*	215*	89*	207	77*	73*	30*
VI	238	225	268	259	247	94	113	109
\bar{M} rates	248	250	239	167*		101	96	67*

L.S.D's @5% rates = 48; stages = 32; S x R = 51

* Indicates significant difference from respective check.

Table XXVI. Effect of Dalapon on bushel weight of oats

Treatment stage	Check	1.5	3.0	6.0	\bar{M} stages	Bushel wt. as % of check		
						1.5	3.0	6.0
I	30.8	33.2	25.0	19.5	27.1	108	81	63
II	35.0	32.5	28.0	20.0	28.9	93	80	57
III	34.2	32.5	25.2	20.5	28.1	95	74	60
IV	32.5	31.2	21.8	--	--	96	67	--
V	33.0	33.2	31.0	24.0	30.7	101	94	73
VI	33.5	32.5	32.7	32.0	32.7	97	97	96
\bar{M} rates	33.2	32.5	27.0	--		98	81	--

Grain yield of oats was severely reduced by the 6 lbs./A. rate applied at any time up to the shot blade stage. The fourth application, at 25 days after emergence, was the most damaging, reducing grain yield to 44 and 5% of the check with three and six pounds of Dalapon per acre, respectively. Straw yield and bushel weight were also most adversely affected by treatments at this date of application.

Yield of flax seed was impaired by all three and six lb./A. treatments applied at all stages prior to near completion of flowering. The 1.5 lb. rate significantly reduced yield of plots treated from emergence until 36 days after emergence. Flax was most susceptible 36 days after emergence, when plants began flowering and buds were plentiful. Yields were reduced to 79, 38, and 8% of check yields by the three rates at the above date of

treatment. Flax straw yield was not reduced except by the high rates applied before emergence of seedlings. The seed yield of both flax and rape was most reduced by Dalapon treatment during the bud and flowering period. In flax, bud-opening was inhibited or delayed. The blue petals in partially opened buds or in fully opened flowers lost most of their color and were almost white in appearance. The buds of treated rape plants did not appear to be adversely affected but petal color was changed to a much lighter shade of yellow. As far as is known, this bleaching of flower pigments by Dalapon has not been previously reported.

The stand of rape was not affected by any rate of Dalapon at any of the six dates of treatment, but significant seed yield reduction occurred when six pounds per acre was applied at 9, 26, and 43 days after emergence, and from all rates of application at 43 days after emergence. In addition, there was a trend towards yield reduction from the 6 lbs./A. rate applied before, and immediately after emergence, that emphasizes need for further study before the period of least susceptibility of rape to Dalapon could be recommended in connection with selective wild oat control. Under the conditions of ^{this} experiment rape tolerated 3 lbs./A. of Dalapon when applied up to nine days after emergence.

Influence of dichloral urea upon protein content of cereal grains

In the discussion of the experiment with seedling toxicants for wild oat control (page 77), it was mentioned that the protein content of oats was significantly raised by dichloral urea

treatments which had no significant effect on yield. This physiological response was considered of sufficient interest to be investigated further. A total of three field experiments and three greenhouse tests were devoted to the study. Data from two field experiments and two greenhouse experiments in which positive responses were obtained are given in Tables XXVII and XXVIII.

In the first field experiment, DCU was applied at 0, 10, and 20 lbs./A., on June 16, 1953, to cultivated oats at the 2 - 3 leaf stage. The experimental area, situated on a farm field, had been continuously cropped for a number of years and was badly infested with wild oats. No wild oat growth occurred that season, however, and observations were therefore confined to herbicidal effects on the crop. On examination at the shot-blade stage, a deep blue-green foliage color was noted on the DCU treated plots, giving an impression of increased vigor. This intensification of foliage color had been noted previously by the writer in a test conducted in 1950 at the Green Cross Insecticides research station at Rougemont, Quebec. In the present test, three - $\frac{1}{2}$ rod rows from the dichloral urea and check plots were harvested for grain yield data. Since analysis revealed no significant effect on yield due to treatment, other effects were looked for. Part of the grain samples were ground in a Wiley mill, analysed for nitrogen by the Macro-Kjeldahl method, and converted to crude protein, using a factor of 6.25. Very low values of protein were obtained contrasted to the normal 11 - 12% for oats. However, protein increases due to treatment, as shown in Table XXVII, were highly significant,

Table XXVII. Grain yield and protein content of oats following foliage treatment with DCU; and increases in nitrogen content of grain compared with pounds of nitrogen added as DCU (8% N). 1953 data are the mean of 3 replicates, 1955 data the mean of 4 replicates.

DCU lbs./A.	Oat yield	Grain* weight	% protein	Pounds per acre of:			
				Grain	Protein	Nitrogen	N increase over check as DCU
<u>Sprayed June 16, 1953</u>							
0	33.6	39.9	7.50	1145	86	13.8	none
10	32.6	35.2	8.20	1112	91	14.6	0.8
20	32.5	35.1	9.90	1107	110	17.6	3.8
I.S.D's @5%	-	-	0.58				
@1%	-	-	0.95				
<u>Sprayed June 16, 1955</u>							
0	27.2	30.3	12.48	925	115	18.4	none
20	28.8	29.0	14.78	979	145	23.2	1.6
40	22.4	28.4	15.58	762	119	19.0	3.2
I.S.D's @5%	3.6	1.4	0.36				
@1%	5.4	2.1	0.54				

* Grain weight, expressed as lbs./bus. in 1953, and as grams per 1000 kernels in 1955.

* Grain weight, expressed as lbs./bus. in 1953, and as grams per 1000 kernels in 1955.

with the increase from the 20 lbs./A. treatment significantly higher than that from the 10 lbs./A. rate. The size of the remaining grain sample did not permit use of a standard apparatus for determination of bushel weight but a rough estimate was obtained by measuring the volume of grain with a graduate cylinder and weighing. The data showed a trend towards reduction in bushel weight of oats from DCU treated plots, though this was not statistically significant.

Following this experiment, a greenhouse test was conducted with wheat, oats, and barley grown in eight-inch-diameter-pots filled with a sterilized greenhouse mixture. Three pots of each cereal per treatment were planted and harvested as three replicates. In addition to simultaneous spraying of both soil and foliage, spray was restricted to the foliage of oats in some treatments by use of an absorptive layer of granular vermiculite poured off the soil surface immediately after spraying the potted material. The plants were in the 2 - 3 leaf stage when sprayed on January 7, 1954, with 0, and 20 lbs./A. of DCU. No visible effect was noted on any of the three cereals during the growth period, and when the matured grain was analysed for protein, no response from treatment could be detected.

In the spring of 1954, a large experiment was laid out on summerfallowed land on the University farm in an effort to determine whether an increase in protein content of oats could again be induced by DCU, and to attempt to find the optimum growth stage for treatment. The experimental design provided for six

dates of treatment as whole plots, and for rates of 0, 10, 20, and 40 lbs./A. of DCU, as split plots. The experiment was replicated four times. Cultivated oats, var. Victory, were sown on May 31, and DCU applied two days later, one day after general emergence, at the 2 - 3 leaf stage, after five weeks of growth, at the shot-blade stage, and 5 - 6 days after flowering.

Analysis of variance on data for bushel weight, and protein content for this experiment revealed no significant differences due to DCU treatment. No visible effect had been noted during the growth period and there was no measurable effect on yield of grain or fresh plot weight from DCU applications made at any time after emergence. As could be expected from the known nature of this herbicide towards seedlings, highly significant reduction of plant weight, and grain yield resulted from the 40 lbs./A. rate applied before emergence. This treatment reduced the fresh weight of corresponding plot samples to 71% of the fresh weight of the check, and lowered the grain yield to 37 bushels per acre, as contrasted with the check yield of 58 bushels per acre. A trend towards yield reduction with the 20 lbs./A. pre-emergence application was shown to be insignificant, either by analysis of variance or when data were paired with check data in a t-test.

Since this experiment was conducted on very fertile soil and in a season of higher than normal rainfall, contrasted to the less fertile soil and drier conditions of the 1953 field experiment, it was thought that increase in the protein content of grain might be induced by DCU treatments only under conditions of lower soil

fertility, and/or low soil moisture supply. As shown in the second half of Table XXVII, a positive response was again obtained in a 1955 field experiment, conducted on land in second successive crop in a farm field within a few miles of the 1953 test. Cultivated oats, var. Exeter, had been sown on May 18, and were treated with 0, 20, and 40 lbs./A., of DCU, 29 days later when the crop was in the advanced third leaf stage. The experiment was replicated four times.

Examination of the crop at the shot blade stage again revealed the marked deepening of the foliage color but both rates of treatment had stunted and delayed maturity of the crop, and caused severe tip burning of the older leaves. Hail occurred about two weeks before maturity, accounting for a low grain yield in the experiment. In spite of herbicidal injury to the foliage, a consistent trend over all replicates towards a somewhat increased yield with the 20 lbs./A. treatment was evident, whereas highly significant yield reduction as well as significant reduction in 1000 kernel weight resulted from the 40 lbs./A. rate. Highly significant increases in protein content were obtained with both rates of DCU, and a highly significant elevation from the 40 lb. rate over the 20 lb. rate. Due to the grain yield reduction from the high rate, diminished returns occurred when the yield of protein was considered on an acre basis. The yield of nitrogen per acre, as shown in Table XXVII, equalled or exceeded the amount of nitrogen added as dichloral urea (8% N) in all 1953 and 1955 treatments, except for the 40 lb. rate as discussed above.

At the same time as the above experiment was in progress, a greenhouse test involving soil of high and low fertility was carried out. A bench was divided into four - 2' x 3' compartments, and filled with soil to a six inch depth. Two compartments received Edmonton, black silty clay loam, and the other two compartments a much less fertile grey-wooded soil. Four rows of Victory oats, and four rows of Thatcher wheat were planted in each, and a compartment of each soil type sprayed with 20 lbs./A. of DCU, when the plants had emerged and were in the 2 - 3 leaf stage. The treated wheat plants did not head, due to a herbicidally induced delay of maturity, and an infestation by grain aphids that was not noted until permanent damage had been done. The oats and the untreated wheat were mature enough to escape aphid damage. No visible effect of chemical treatment could be noted on the oat foliage during plant growth. Data for protein content of the grain, as shown in Table XVIII, indicate increases for oats from both soil types, and in particular from the less fertile grey-wooded soil.

Table XXVIII. Influence of soil type on effect of dichloral urea on protein content of oats and wheat, and starchiness of wheat (greenhouse tests, oat data - summer, 1955; wheat data - winter, 1955-56).

Soil type	DCU lbs./A.	% protein content		1000 kernel wt. of wheat (grams)	% starchy wheat kernels
		oats	wheat		
Black, silty clay loam	0	11.4	12.8	32.6	5.4
Black, silty clay loam	20	11.8	12.5	32.2	3.4
Grey wooded	0	11.4	14.2	32.8	4.3
Grey wooded	20	13.9	15.0	32.5	2.7

This greenhouse experiment was repeated using the same soil for retreatment. Prior to the second test, the soil was repeatedly and heavily watered in an effort to leach out any residual herbicide. Wheat and oats were planted on October 8, 1955, and sprayed with 20 lbs./A. of DCU when in the third leaf stage. These tests were conducted in a new greenhouse, with supplementary lighting not installed until January, accounting in part for a very slow growth under the short days of the second test. No visible effect from treatment was noted on the oat plants, but due to the unfavorable conditions for growth, almost all of the seed produced was sterile. No adverse effect from treatment was noted on wheat until about one month after treatment. The older leaves, which had been present at the time of spraying, suffered serious tip-burn and plants were stunted. All treated plants subsequently recovered and appeared to be as well developed at the time of harvest as the check wheat plants. Protein analysis at maturity indicated an increase in protein content attributable to treatment of wheat plants grown in the grey-wooded soil. The percentage of starchy, "piebald", wheat kernels was lessened by treatment in both soil types. The 1000 kernel weight of wheat seed from either soil type was only slightly reduced by the chemical. It is of interest to note that Reeves (31) was able to decrease the percentage of mottled grain and improve the baking quality of wheat by foliage applications of urea.

When the results of all field and greenhouse tests are considered, there is very little doubt that the protein content of small grains can be elevated by dichloral urea treatment, but

consistent increase can apparently only be obtained under conditions of low soil fertility. The amount of increase of grain nitrogen per acre associated with DCU exceeded the amount added as DCU, where the yield of grain was not depressed. Thus it would appear that the effect of treatment was not confined to a fertilization effect, but that more complex physiological processes were involved. This view is compatible with the observation that in the experiments in which an intensification of foliage-color was noted following chemical treatment, none of the typical nitrogen deficiency symptoms appeared in the check plots.

Effect of stubble fire and oven heat on germination of wild oats

Wild oat seed and wheat heads were collected from the soil surface in heavy wheat stubble, before and after burning. Burning was done on September 7, 1953, three days after combining the swathed crop. The straw had been well distributed by a spreader, and an air temperature of above 80° F. served to promote a hot thorough burn. Three germination tests were conducted on the two lots of wheat and wild oat seed with results as shown in Table XXIX. In the first two experiments, 50 seeds per test were placed in slotted holes in a special "rag-doll" type of germinator pad, and held at room temperature in a closed jar to maintain constant humidity. This method did not prove very satisfactory since mold contamination developed quickly, especially in fire killed seed. In the third test folded paper towels were utilized with excellent results in a humid germination cabinet held at 20° C. Complete after-ripening of seeds which had taken place during their storage for one year after collection contributed to the improved germination in 1954.

Table XXIX. Effect of stubble fire on germination of wheat and wild oat seed from the soil surface

Seed and source	Percentage germination		
	September, 1953	November, 1953	August, 1954
Wheat - unburned stubble	60	-	100
Wheat - burned stubble	0	-	0
Wild oats - unburned stubble	20	10	100
Wild oats - burned stubble	6	0	-
Wild oats - burned stubble, seed apparently unharmed*			6
Wild oats - burned stubble, seed lightly scorched*			3

* Wild oat seed from the burned stubble was separated in the third germination test into two groups according to the degree of visible injury.

The viability of the wheat seed was totally destroyed during burning of the stubble. The wheat seed itself was not visibly harmed by the fire, being protected from direct contact by enclosure in the head. All heads, however, were scorched to some degree. Nearly 100% of the wild oat seeds were killed, even though no visible sign of fire injury could be found on the hull.

It is relevant to note that following burning of stubble in the 1955 fall-season, in experiments by Molberg and Leggett (29), the number of wild oats germinating the next spring was reduced by 53% as compared to controls. McCurdy (26), on the other hand, obtained a stimulation of germination of 163 and 445%, with and without fall disking, respectively, after burning. It is the belief of many farmers that burning serves to encourage germination of wild

oats so they may be killed by tillage or fall frost. In addition to direct effects on the seed coat, this stimulation may be partially the result of a more favorable seed bed, especially when tillage follows burning.

Rincher (32a) secured marked increases in the germination of hard seeded sweet clover seed by short exposure to high temperature, and found the induced stimulation of germinability persisted after long periods of storage. To determine the effect of controlled high temperature on wild oat germination, small lots of stock seed were placed in a forced-air-oven for various periods of time, at various temperatures. The exposed seed was sampled in a random manner by means of a vacuum operated seed counter, and tested for germinability, using the folded paper towel method. Unheated check seeds gave a mean germination of 72%, indicating that some degree of dormancy was still present despite several months of dry, laboratory storage. Germination data for wild oat seed exposed to 150, 175, 200, 250, and 400° F. are plotted against time of exposure in Fig. 17.

Exposure of dry wild oat seeds to temperatures above the boiling point of water quickly destroyed germination. Only 4% germination resulted after a one minute exposure to 400° F. This temperature caused the endosperm of many seeds to burst as a result of pressures built up from internal moisture. Exposure at 250° F. for one or two minutes stimulated germination, but death of all seed occurred from five minutes' exposure. A marked stimulation of germination, followed by a loss of viability with time,

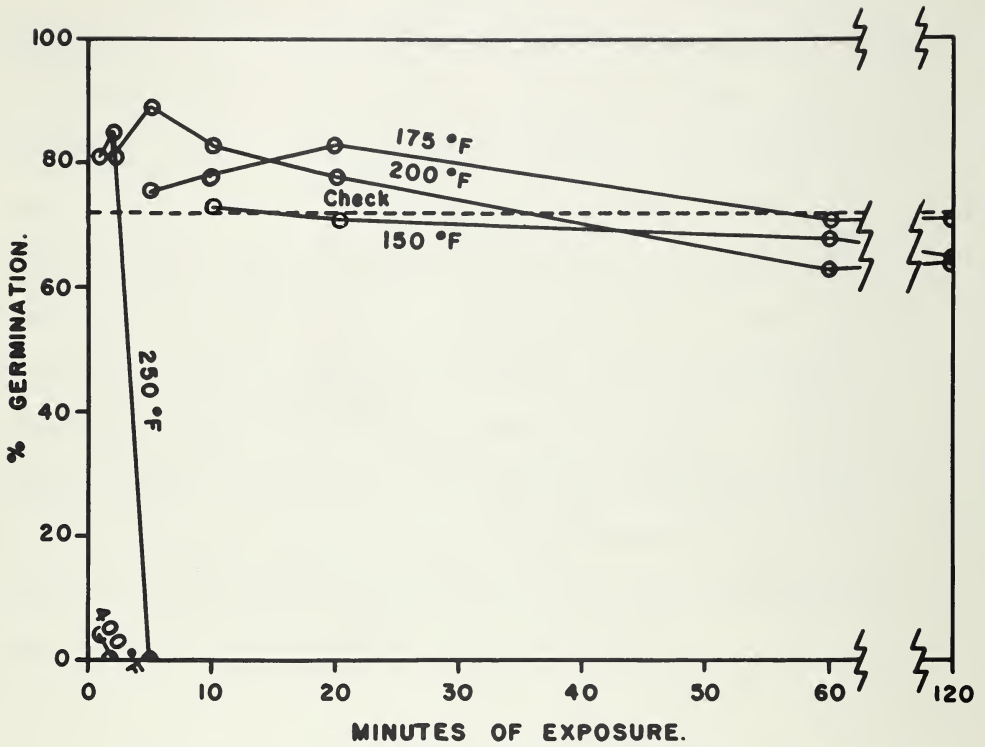


Fig. 17. Influence of heat on wild oat germination, each point on the graph is a mean of three - 50 seeds germination tests.

resulted from temperatures of 200 and 175° F. Germination of seed exposed to 150° F. was similar to that of the check seed, although a trend towards damage occurred after long exposure.

In agreement with views expressed by Rincher (32a), on the basis of results with hard coated legume seeds, it seems logical to assume that two processes were operating, one a high temperature effect on the seed coat, promoting a breakage of dormancy, and the other a thermal inactivation of the vital processes of the seed, which appeared cumulative with increasing time of exposure. From these results it may be deduced that a stubble fire, depending on intensity and speed of burning, may affect wild oat seed on the soil surface either by killing the seed, or by promotion of germination, or both. Under heat conditions stimulating germination, the effect may be greater on a more dormant sample of freshly shattered seed than was the case with the partially after-ripened seed used in the above heat exposure experiment.

DISCUSSION AND CONCLUSIONS

The foregoing results represent experiments involving a variety of objectives, chemicals, and procedures relevant to control of wild oats, and with the influence of these chemicals on crop plants. The following general statements appear to be warranted by the experimental evidence, considered also in the light of other available information on the subject.

TCA, extensively tested as a short term soil sterilant, did not provide worth-while reduction of wild oat plants unless applied at very heavy dosages, and even when applied in the fall caused dangerous residual toxicity which seriously limited the growth of crops planted during the next growing season. Dalapon, similar in chemical structure and in mode of action to TCA, proved much more effective and may have a shorter residual toxicity. In the one experiment involving treatments in springtime in which the two chemicals were directly compared, 10 lbs./A. of Dalapon produced four times the green weight reduction of wild oats as TCA at 50 lbs./A. and effectively prevented heading. Both TCA and Dalapon exerted their effect chiefly through suppression of growth rather than by extensive "kill" of wild oat plants. Dalapon, in contrast to TCA, is taken in through the leaves as well as the roots, and proved effective as a foliar spray at rates as low as 5 lbs./A. Although TCA has found a place in the control of Setaria spp. in flax, this crop did not safely tolerate Dalapon at any stage of growth at rates as low as 1.5 lbs./A. Argentine rape appeared to

possess enough resistance to 3 lbs./A. of Dalapon, when applied up to nine days after emergence, to warrant its use when a measure of wild oat control would balance possible deleterious effect on the crop plant. The control of grassy weeds in sugar beets with post-emergence applications of Dalapon has been reported to be feasible (2, 6). The effect of fall-application of Dalapon and of its incorporation into the soil by tillage was not investigated. From the results with TCA it might follow that fall-application would be superior to spring-application, and that incorporation by tillage would not be desirable. The results from the literature, as summarized in table VII, favor spring application and non-incorporation of Dalapon. It would appear that freely soluble herbicides like TCA and Dalapon may be moved to the seedling root zone as a more or less concentrated front by relatively small amounts of precipitation, whereas incorporation by tillage may only serve to disperse and dilute the effective concentration of herbicide.

The carbamate herbicides, IPC and CIPC, and the acetamide, CDAA, applied at much lower rates, proved much superior to TCA and exerted their effects chiefly in the killing of wild oat germinants and young emerged seedlings. CIPC consistently proved more effective against wild oats than IPC but this advantage is somewhat lessened by the less selective properties and longer residual toxicity of CIPC. IPC is at present the only chemical which has been recommended for wild oat control in Canada, and only for certain resistant crops such as sugar beets and field peas (35). Nelson (30) reported good control of wild oats in sugar beets

with 3 - 6 lbs./A. of IPC in 8 out of 15 field trials using the pre-planting method and thorough incorporation of the chemical with the top layer of soil. Based on a large number of trials in Idaho and Washington, Seely (34) found that use of 4 lbs./A. of IPC gave 85% control of wild oats, which resulted in more than double the yield of field peas than obtained from untreated weedy land. Certain other crops such as alfalfa, sunflowers, rape, soybeans, corn, potatoes, and onions have been shown to tolerate sufficiently high rates of IPC to permit selective control of wild oats (3, 41, 43). In the present tests fall application of the carbamate herbicides was found to give better control of wild oats than spring application and with the exception of one trial, these relatively insoluble chemicals proved most effective when incorporated into the soil by tillage.

CDAA, though tested at a lower range of rates than the carbamates, produced similar results, and under certain conditions superior results, as a pre-planting or as a pre-emergence herbicide. A large number of crop plants have been reported to be tolerant (7, 18). CDAA appeared to possess a relatively short period of residual toxicity and was not suited for fall application. The results with soil incorporation of CDAA were variable. Incorporation of CDAA appeared necessary under dry soil conditions but when precipitation followed application, incorporation was not necessary or desirable. A striking positive correlation was noted between the effectiveness of non-incorporated CDAA and the amount of rainfall occurring between application of chemical and the emergence

of wild oats. With the carbamates, IPC and CIPC, a moderate degree of soil moisture and rainfall following incorporation appeared to produce optimum results. Thoroughness of incorporation, however, was of greater influence than precipitation. Germination tests of wild oat seeds situated at the soil surface carried out after treatment with IPC, and laboratory experiments in which chemicals were sprayed directly on the seed surface, showed that IPC and CIPC were strongly adsorbed by the hull in amounts sufficient to prevent germination. Somewhat comparable field tests involving CIPC and CDAA indicate the desirability of direct sprays to seed shattered on the surface of stubble ground rather than a general soil application after the seed has worked its way or been tilled into the soil. This would seem to be a sound method in that subsequent tillage would tend to turn the chemical and the surface wild oat seed into the soil at the same relative position. Under conditions of intimate contact of herbicides and seed in laboratory experiments, some direct kill of seed prior to actual germination was indicated. Under field conditions, however, it would appear that seed is fairly well protected against herbicidal effect until some degree of sprouting occurs. This is a factor which should be further investigated for if very little "fumigation effect" from a herbicide takes place, dormant seeds would be unharmed and it is likely that healthy wild oat plants would be produced following the disappearance of residual toxicity.

Field and laboratory tests indicated that satisfactory, safe, pre-emergence treatment of cereals and flax with CDAA could not be expected under conditions favoring optimum control of wild

oats, even though flax possessed considerable resistance to CDAA and wild oats were much more susceptible than wheat and barley. Pre-planting applications of CDAA, followed by thorough incorporation of the chemical into the soil, and delayed seeding of crops, may prove to be a better approach. Field trials of this method by other workers have produced variable but encouraging results (24). CDAA appeared to be relatively harmless to crops when applied as a foliar spray. As indicated by greenhouse tests, a promising use of the chemical may be the residual post-emergence treatment of cereals and flax to protect the crop against late emerging wild oats and certain other weeds. This method, if proved feasible, would permit very early seeding and thus be superior from the standpoint of crop yield than any method of control involving delayed seeding. Since incorporation of chemicals into the soil is not possible with post-emergence treatment, success would be dependent upon adequate rainfall occurring between treatment and wild oat emergence.

None of the chemicals tested as foliar sprays proved consistently reliable enough for good contact pre-emergence control of wild oats. DNBP in one test gave almost complete control at rates as low as 5 lbs./A. when applied in diesel oil but gave poor results in other tests and when applied as a water emulsion. Wild oat plants that had not been killed within a day of treatment with contact herbicides were usually able to resume growth. Other herbicides, such as Dalapon and amino-triazole, that were systemic in action, gave good control but since they produced residual toxicity

may only be useful in certain resistant crops. The amine formulation of maleic hydrazide produced no evidence of residual effect and was of interest in that 10 lbs./A. usually produced good kill of wild oats, and escapes were stunted to the extent that little heading took place. This chemical has been suggested by Warren and Bronson (38) as suitable for the contact pre-emergence control method. With this method the crop could be sown directly into a wild oat growth which would then be destroyed by foliage sprays before crop emergence. The advantages of this method, as outlined in the introduction, do not appear to balance the uncertainties, such as possible interference with timely spraying by unsuitable weather.

Of the varied approaches to chemical control, one of the most consistently successful techniques throughout the entire wild oat problem area has been the selective induction of seed sterility in maturing wild oats by means of properly timed maleic hydrazide treatment. The present investigations showed that seed from plants treated with MH had normally developed endosperms but were embryoless or had embryos which were disorganized or smaller in size. As could be expected from the short period of kernel development in which sterility can be induced, the seed from tillers maturing at different times was not equally affected by treatment. This weakness of the method may not prove too serious under actual farm conditions where the phenology of the weed population is rendered more regular by crop competition. Since the upper whorls of the wild oat panicle mature and shatter several days ahead of the lower

whorls, these upper kernel positions should govern the timing of MH application rather than the lower kernels, which are more apt to be harvested with the crop and removed from the field. This criterion unfortunately lessens the differences at the time of spraying between the kernel development of crop and weed upon which selectivity depends. From the information presently available, only early maturing barley varieties, such as Olli, are sufficiently ahead of wild oats in phasic development to permit a high degree of selectivity. The risk of lowering the germinability of a treated crop would appear to rule out the use of the method in crops intended for seed or for malting purposes. If tests on toxicity of chemical residue on grain and straw show no problem in this connection, the use of the method in crops intended for farm consumption as livestock feed would appear to be practical, since germinability is not a factor and there is no evidence of yield reduction from treatment after kernel development has begun.

As outlined in the above discussion, chemical control measures which do show promise against the wild oat have narrow limitations imposed by the high resistance of the weed, cost of chemicals, climatic factors, adaptation to cultural practices, and use only with crops which permit a practical degree of selectivity. The difference over a period of years, between a gradually increasing infestation and the alternative of suppression to a level permitting profitable crop production, however, may lie in the utilization, whenever possible, of such supplementary control methods.

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